

Investigating Opposing Aftereffects in 8-year-olds and Adults

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Abstract

Previous studies have shown that adults and 8-year-olds process faces using norm-based coding and that prolonged exposure to one kind of facial distortion (e.g., compressed features) temporarily shifts the prototype, a process called adaptation, making similarly distorted faces appear more attractive (Anzures et al., 2009; Valentine, 1999; Webster & MacLin, 1999). Aftereffects provide evidence that our prototype is continually updated by experience. When adults are adapted to two face categories (e.g., Caucasian and Chinese; male and female) distorted in opposing directions (e.g., expanded vs. compressed), their attractiveness ratings shift in opposite directions (Bestelmeyer et al., 2008; Jaquet et al., 2007), indicating that adults have dissociable prototypes for some face categories.

I created a novel method to investigate whether children show opposing aftereffects. Children and adults were adapted to Caucasian and Chinese faces distorted in opposite directions in the context of a computerized storybook. When testing adults to validate my method, I discovered that opposing aftereffects are contingent on how participants categorize faces and that this categorization is dependent on the context in which adapting stimuli are presented. Opposing aftereffects for Caucasian and Chinese faces were evident when the salience of race was exaggerated by presenting faces in the context of racially segregated birthday parties; expanded faces selected as most normal more often for the race of face that was expanded during adaptation than for the race of face that was compressed. However, opposing aftereffects were not evident when members of the two groups were presented engaging in cooperative social interactions at a racially integrated birthday party. Using the storybook that emphasized face race I

provide the first evidence that 8-year-olds demonstrate opposing aftereffects for two face categories defined by race, both when judging face normality and when rating attractiveness.

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1

Investigating Opposing Aftereffects in 8-year-olds and Adults

Adults' Face Space

Norm-Based Coding in Adults

Adults have a remarkable ability to discriminate and recognize hundreds of faces based on small differences in both featural and spatial cues (Bahrick, Bahrick, & Wittlinger, 1975; Freire, Lee, & Simons, 2000; Mondloch, Le Grand, & Maurer, 2002; reviewed in Maurer, Le Grand, & Mondloch, 2002). Adults' expertise has been attributed to norm-based coding, a process of encoding individual face exemplars relative to a face prototype (Valentine, 1991). An individual's prototype is a face composite created by averaging all of the faces a person has seen together, making it the most average or typical of faces. The kinds of faces most commonly seen, typically upright own-race faces, have the largest impact on the composition of the face prototype.

The prototype is thought to act as a reference point located in the center of a multidimensional face space. Faces are encoded on multiple dimensions with each dimension representing multiple face characteristics such as eye shape, eye colour, and distance between the eyes and mouth (Nishimura, Maurer, Gao, in press; Valentine, 1991). The location of a specific face in face space is determined by its values on these multiple dimensions, with faces rated as highly similar having similar values (Nishimura et al., in press; Potter & Corneille, 2008; Valentine, 1991). Identity vectors connect each individual face to the prototype and the length of the vector indicates how similar each exemplar is to the prototype. Faces with short identity vectors (i.e., faces near the prototype) are rated as more typical or normal looking (Langlois & Roggman, 1990; Rhodes, Sumich & Byatt, 1999; Rhodes & Tremewan, 1996; Valentine, 1991) and as

more attractive than faces with long identity vectors (i.e., faces far from the prototype: Langlois & Roggman, 1990; Potter & Corneille, 2008). One reason for this is that adults prefer prototypical things (Winkielman, Halberstadt, Fazendeiro, & Catty, 2006) and faces that are most similar to the face prototype are more prototypical in appearance than faces that are less similar. This prototype theory also explains another robust finding: face composites, created by averaging several faces together, are rated as more attractive than most or all of the individual faces used to create the composite (Langlois & Roggman, 1990), presumably because the averaged face is more similar to the prototype than the individual faces.

Faces similar to the prototype (i.e., typical faces and attractive faces) form high-density clusters around the prototype (Potter & Corneille, 2008; Valentine, 1991). The density of face space influences both the ease with which a stimulus is detected as a face and the ease with which it is recognized at the individual level. Valentine (1991) demonstrated that typical faces are more easily recognized as a face in a face/non-face task, but that atypical faces are recognized more rapidly at the individual level. These findings are attributed to the high-density face clusters. Typical faces not only share similarities with the prototype but they also share similar facial characteristics with one another, because they are located in similar regions within face space and have similar vector lengths (Potter & Corneille, 2008). In contrast, faces that are more distinctive are located further from the prototype and are dispersed throughout the outer regions of face space. Atypical faces also share relatively few similarities amongst one another (e.g., Prince Charles has large ears whereas Brian Mulroney has a large chin), resulting in less time required to discriminate amongst these faces.

Not only do the kinds of faces seen impact the composition of the prototype but these faces also impact the dimensions on which faces are encoded. The dimensions used to discriminate faces are optimal for the faces to which an individual has primarily been exposed (typically upright human faces of the same race). According to Valentine's norm-based coding model, both the other-race effect (adults' impaired ability to discriminate and recognize other-race faces relative to own-race faces: Sangrigoli & de Schonen, 2004a; Sangrigoli & de Schonen, 2004b; Valentine & Endo, 1992) and the inversion effect (adults' impaired ability to recognize inverted faces: Bartlett & Searcy, 1993; Pellicano & Rhodes, 2003) are the result of the dimensions in face space being optimal for distinguishing upright own-race faces, but not for distinguishing inverted or other-race faces.

Like atypical own-race faces, other-race faces are considered distinctive and are located further from the prototype (Valentine, 1991; Valentine & Endo, 1992). However, unlike atypical own-race faces, other-race faces differ from the prototype in the same way (e.g., skin color, featural shapes), forming a high-density face cluster out in face space. One reason for this could be that the dimensions required for discriminating own-race faces are less suited for discriminating other-race faces, creating other-race face clusters in the outer regions of face space and resulting in less differentiation among other-race faces. Therefore, other-race faces are quickly identified as an other-race face but are harder to recognize at the individual level (Valentine, 1991). A similar explanation could be given to explain our impaired ability to recognize inverted faces (Bartlett & Searcy, 1993; Pellicano & Rhodes, 2003).

Adaptation in adults. Compelling evidence has been shown, using facial adaptation paradigms, that adults' face prototype is continuously updated as new faces are encountered (Anzures, Mondloch, & Lackner, 2009; Bestlemeyer, et al., 2008; Jaquet & Rhodes, 2008; Jaquet, Rhodes, & Hayward, 2007; Little, DeBruine, & Jones, 2005; Little, DeBruine, Jones, & Waitt, 2008; Rhodes, Jeffery, Watson, Clifford & Nakayama, 2003; Webster & MacLin, 1999). One way in which the face prototype has been studied is through a process known as identity aftereffects (see Leopold, O'Toole, Vetter, & Blanz, 2001; Andersen & Wilson, 2005; refer to Figure 1). This task involves morphing several face identities (e.g., Bob, Dan, Tom and John) together to create an averaged composite face (i.e., similar to a face prototype). Next a face continuum is created using an individual face identity, (e.g., Bob), by morphing the facial identity with the prototype face in incremental steps. This continuum is an identity trajectory (similar to a vector which codes for face identity). The relative weighting of the individual identity and the average face determines identity strength; a face with 80% identity will be easily recognized as Bob, whereas a face with 10% identity is likely to be labeled Jim or Dan. After adaptation to a computationally opposite face (e.g., anti-Bob) previously ambiguous faces (e.g., 10% Bob) are readily identified, presumably because the prototype has shifted toward the anti-identity, thus making the previously weak identity farther away from the prototype.

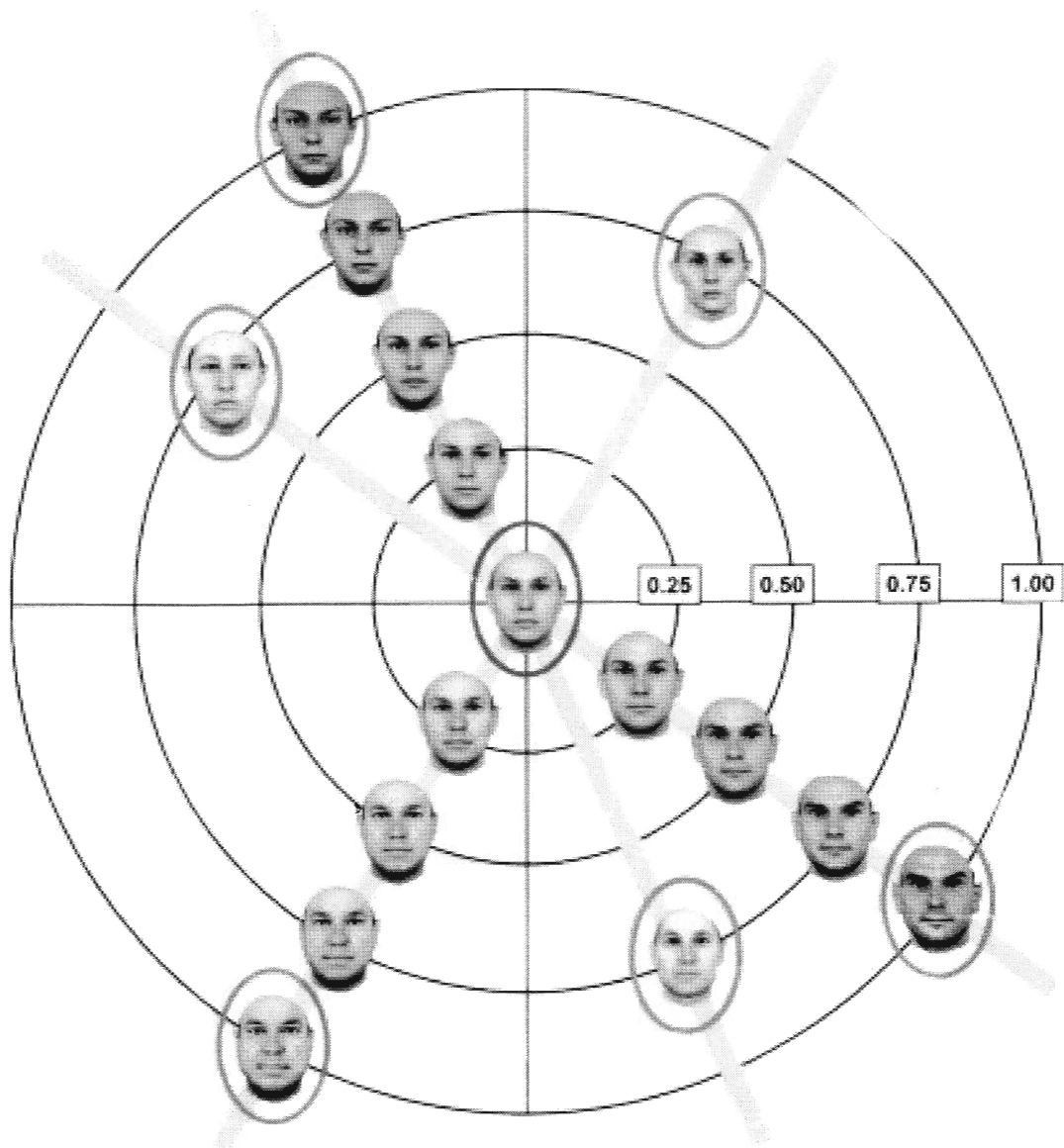


Figure 1. A depiction of a computationally derived face space used to elicit identity aftereffects. The faces in the green circles are the identities (e.g., Bob), the faces in the red circles are the anti-identities (e.g., anti-Bob) and the face in the blue circle is the averaged composite face.

Obtained from Leopold, O'Toole, Vetter, & Blanz (2001).

Simple adaptation aftereffects for many face characteristics including attractiveness, sex, race and expression have also been shown in adults (Andersen & Wilson, 2005; Anzures et al., 2009; Jaquet & Rhodes, 2008; Leopold, et al., 2001; Rhodes et al., 2003; Webster & MacLin, 1999; Webster, Kaping, Mizokami & Duhamel, 2004). Typically these studies consist of three phases; a pre-adaptation rating phase, an adaptation phase and a post-adaptation rating phase. Aftereffects are then measured by comparing the difference in pre- and post-adaptation ratings. This is an example of how one of these simple aftereffect studies would be conducted. First participants are asked to judge a series of rating faces (e.g., faces with compressed, unaltered and expanded features) on one of several characteristics (e.g., normality or attractiveness). Next, participants are adapted (via prolonged exposure) to one type of face (e.g., faces with compressed features) for a set time period. Lastly, participants are asked to rate another series of faces. Evidence of adaptation aftereffects would be shown if, following adaptation, ratings for faces similar to those seen during adaptation (e.g., with compressed features) increased on normality or attractiveness while other characteristics did not. This increase in ratings would suggest that the face prototype has shifted towards the adapting stimuli (i.e., towards compressed features), moving undistorted faces away from the prototype.

These face adaptation aftereffects parallel those reported for a variety of visual domains (Ibbotson, 2005; Leopold & Bondar, 2005; Webster, 2004): Following adaptation to a waterfall, a stationary pattern appears to move upward (reviewed in Leopold & Bondar, 2005) and following adaptation to a red square, a green square appears on a white sheet (Hering, 1964). These adaptation aftereffects have been

attributed to reduced neural activation following repeated stimulation (Ibbotson, 2005) and appear to be related to our nervous system's attempt at maintaining equilibrium or a sense of normality within continuously changing environments (Webster, 2004).

Multiple face prototypes. Until recently there has been no reason to question Valentine's (1991) face prototype model, however, three new lines of research suggest that adults' face space may have multiple face prototypes instead of one. First, composite faces comprised of only male or only female faces are rated as less distinct than composite faces comprised of both male and female faces (Badouin & Galloway, 2006), as would be predicted if separate prototypes are formed for these two face categories. Second, although adaptation of one face category (e.g., female) generalizes to a second face category (e.g., male) (Jaquet & Rhodes, 2008), the aftereffects are much weaker for the second face category, suggesting that these two categories are dissociable. Third, opposing aftereffects suggest that the prototypes of two face categories (e.g., Chinese versus Caucasian) can be shifted in opposite directions (Jaquet, Rhodes, & Hayward, 2008). For example, after adaptation to Chinese faces with compressed features and Caucasian faces with expanded features normality ratings increase for compressed Chinese faces and expanded Caucasian faces, but not for expanded Chinese or compressed Caucasian faces. Opposing aftereffects also have been shown for upright and inverted faces (Rhodes, Jeffery, Watson, Jaquet, Winkler & Clifford, 2004), old and young faces, Caucasian and African faces and human and monkey faces (Little, et al., 2008).

Although physical differences between the two face categories may be necessary, two recent studies suggest that they may not be sufficient. These studies both suggest that

the two face categories must be socially meaningful. The first study performed by Jaquet et al. (2007) had adult participants adapt to two face sets with opposing distortions under one of two conditions (refer to Figure 2). In one condition, *between categories*, participants adapted to Caucasian and Chinese faces with opposite distortions. Each Caucasian face was created by averaging four Caucasian faces together and each Chinese face was created by averaging four Chinese faces together. These averaged face composites were created to minimize unique facial characteristics within an individual face and to enhance facial characteristics associated with each race. In the second condition, *within categories*, participants adapted to either Chinese and super-Chinese or Caucasian and super-Caucasian faces with opposite facial distortions. The creation of these faces occurred in two stages. First the averaged Caucasian and averaged Chinese faces were randomly paired with one another. Second faces within each pair were warped away from one another creating super-faces. The super-faces were created to exaggerate, by 100%, the typical facial characteristics associated with Caucasian faces and Chinese faces. The physical facial differences between the Caucasian faces and the Chinese faces were equal to the physical differences between the Chinese and the super-Chinese faces and between the Caucasian and the super-Caucasian faces. Opposing aftereffects were observed for the *between-category* faces, i.e., Caucasian and Chinese faces, but there were no opposing aftereffects for the *within-category* faces, i.e., Chinese and super-Chinese faces and Caucasian and super-Caucasian faces.

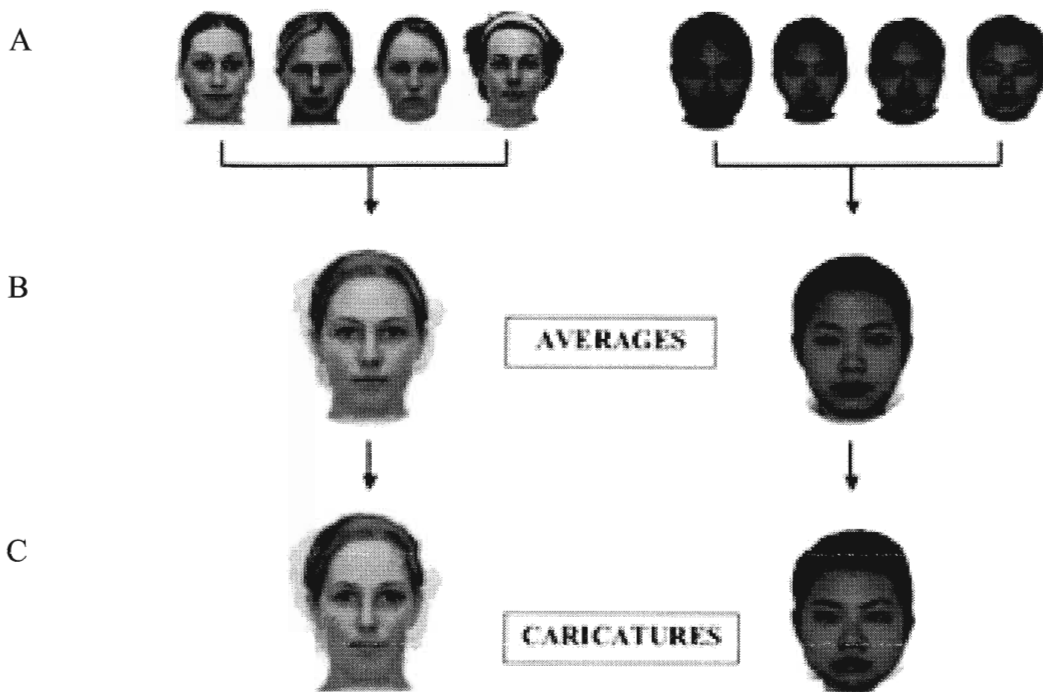


Figure 2. Examples of stimuli used to elicit opposing aftereffects. A: Four individual face identities used to create one averaged face. B: An example of an averaged Caucasian face composite and an averaged Chinese face composite. C: An example of a super-Caucasian face and a super-Chinese face.

Obtained from Jaquet, Rhodes & Hayward (2007)

The second study, performed by Bestelmeyer et al. (2008) yielded similar results. In one condition, *between-category*, participants were adapted to male and female faces whereas in the other condition, *within-category*, participants were adapted to female and hyper-female faces. Like Jaquet et al. (2007) the physical difference between the male and the female faces were made to be equal to the physical differences between the female and hyper-female faces. Unlike Jaquet et al. (2007), Bestelmeyer et al. (2008) found opposing aftereffects for both the between- and the within-category adaptation paradigms. However, consistent with the hypothesis that social categories are important, the observed aftereffects were larger for between-category faces, e.g., male and female, than within-category faces, e.g., female and hyper-female (Bestelmeyer et al., 2008).

Collectively the results from these two studies (Bestelmeyer et al., 2008; Jaquet et al., 2007) suggest that eliciting opposing aftereffects is not only dependent on the degree to which faces physically differ from one another, but also on how the faces are categorized. Opposing aftereffects were observed to be present or strongest for faces that belonged to two distinct facial categories (e.g., Caucasian faces and Chinese faces), rather than when they were at the extremes within a single category, (e.g., Chinese and super-Chinese).

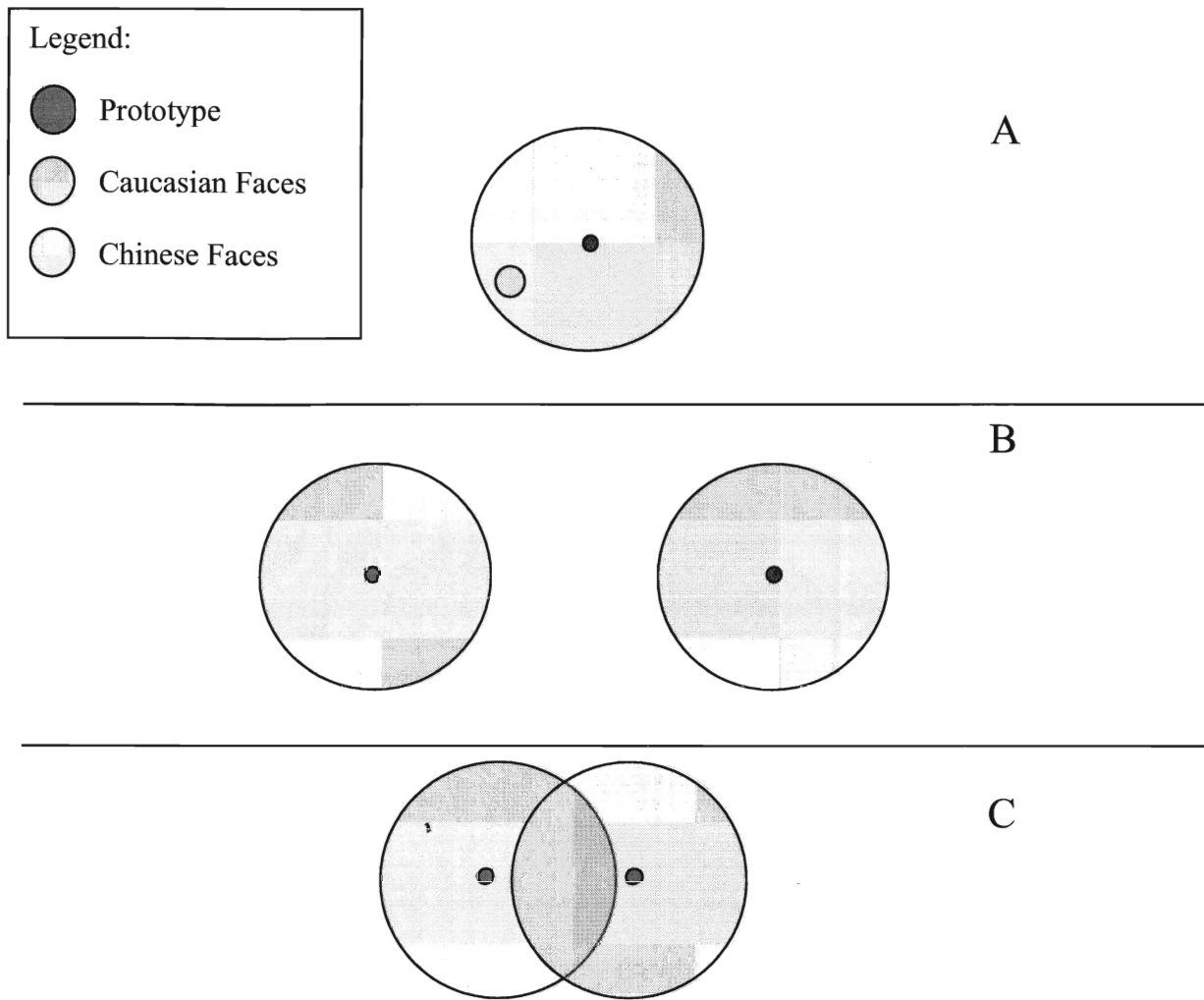


Figure 3. An illustration of three current face-processing models. A: An illustration of Valentine's (1991) face prototype and face space. B: A depiction of Jaquet et al.'s (2008) model for independent neuronal coding of distinct face categories. C: An illustration of Jaquet et al.'s (2008) model for dissociable neuronal coding for face categories. The overlap of the two circles represent neural populations that respond to both face categories (e.g., Caucasian and Chinese faces).

Face Prototype Models

In Figure 3, there are three face-processing models depicted. All three of the models are based on the assumption that adults process faces using norm-based coding. However two of the three models state that adults have multiple face prototypes instead of one. The first model (A) shown is Valentine's (1991) norm-based coding model in which there is a single face prototype and all faces are processed in relation to this one central face. To understand the properties of this model please refer back to the norm-based coding section (p. 1).

The second model (B) suggests the possibility that adults have multiple prototypes that are independent from one another (Jaquet et al., 2008). Each face category has its own unique face space with its own facial dimensions. These prototypes function in similar capacities to the prototype proposed by Valentine (1991). The number of dimensions may be larger for the category with which the observer has the most experience (e.g., own-race faces), making faces from that category easier to discriminate and recognize. This model is sufficient for our understanding of both the occurrences of the other-race effect (Sangrigoli & de Schonen, 2004a, 2004b; Valentine & Endo, 1992) and opposing aftereffects (Jaquet, et al., 2008; Little, et al., 2008; Rhodes, et al., 2004), however, it is not useful for explaining the occurrence of adaptation generalization (when adapted to female faces simple aftereffects were shown for male faces; Jaquet & Rhodes, 2008) and the occurrence of within-category opposing aftereffects (when adapted to female and hyper-female faces small aftereffects were observed; Jaquet et al., 2007).

The third model (C) by Jaquet et al. (2008) suggests that adults have dissociable prototypes. This means that the dimensions associated with each prototype overlap,

allowing for the simple aftereffects from one category (e.g., female) to generalize to another (e.g., male; Jaquet & Rhodes, 2008). Similar to the independent prototype model, the number of dimensions may be larger for the category with which the observer has the most experience (e.g., own-race faces), making faces from that category easier to discriminate and recognize. However, in this model, the more experience an individual has with two or more facial categories the more overlapping/or sharing of facial encoding dimensions these prototypes have. This observed overlap and sharing might explain why there are generalized simple aftereffects shown for male faces following adaptation to female faces (Jaquet & Rhodes, 2008).

Summary

Adults appear to process faces using norm-based coding (Valentine, 1991). The length of an identity vector that projects out from the prototype is used to determine how similar a face is to the prototype; the shorter the vector, the more similar the face is to the prototype. Faces that cluster closely around the prototype are rated as more typical or attractive, whereas faces that are located further out in face space (e.g., faces with an especially large nose or high-placed features) are thought to be distinctive or atypical (Valentine, 1991). Simple adaptation paradigms demonstrate that our prototype is dependent on the kind of face experience we receive and is dynamically updated as we encounter new faces (Andersen & Wilson, 2005; Anzures et al., 2009; Bestelmeyer et al., 2008; Jaquet & Rhodes, 2008; Leopold et al., 2001; Rhodes et al., 2003; Webster & MacLin, 1999; Webster et al., 2004). Evidence from opposing aftereffects suggests that adults may have more than one prototype (Bestelmeyer et al., 2008; Jaquet et al., 2007; Jaquet et al., 2008; Little et al., 2008; Rhodes et al., 2004). These multiple face

prototypes are suggested to be reflective of social or personal groups rather than based solely on physical differences (Bestelmeyer et al., 2008; Jaquet et al., 2007).

The Development of Face Space

Norm-Based Coding in Children

Although it is unknown whether young infants process faces using norm-based coding, there is evidence that infants have a face space that is being shaped by visual experience (Bar-Heim, Ziv, Lamy, & Hodes, 2006; de Haan, Johnson, Maurer, & Perrett, 2001; Langlois, Ritter, Roggman, & Vaughn, 1991; Pascalis, de Haan, & Nelson, 2002; Pascalis, Scott, Kelly, Shannon, Nicholson, Coleman et al., 2005; Sangrigoli & de Schonen, 2004a; 2004b). By 3-months infants can form a face prototype based on a set of faces they were familiarized within a laboratory (de Haan et al., 2001). In addition, by 5-months infants look longer at faces previously rated as attractive by adults than faces previously rated as unattractive (Langlois et al., 1991); by 3-months babies look longer at own-race than other-race faces, unless they have been exposed to both races (Bar-Heim et al., 2006), and by 6- to 9-months babies discriminate own-race human faces, but not other-race human faces or monkey faces (Pascalis et al., 2002; Pascalis et al., 2005; Sangrigoli & de Schonen, 2004a; 2004b).

Studies investigating face perception during early childhood also provide evidence of a developing face space and face prototype. Like adults, children recognize atypical faces more accurately than typical faces (Gilchrist & McKone, 2003), upright faces more accurately than inverted faces (Pelicano, & Rhodes, 2003) and own-race faces more accurately than other-race faces (Sangrigoli & de Schonen, 2004a; 2004b).

Children's ability to recognize and discriminate faces develops gradually and matures over the course of childhood and adolescence (Gilchrist & McKone, 2003; Mondloch, Ahola, & Maurer, 2006; Mondloch et al., 2002; Pelicano, & Rhodes, 2003; Sangrigoli & de Schonen, 2004b). This gradual development cannot be solely attributed to the development of other basic cognitive processes, i.e., attention and memory. Even after these demands are controlled for, children still make more errors than adults on a variety of face perception tasks (Bruce, Campbell, Doherty-Sneddon, Import, Langton, McAuley et al, 2000; Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Geldart, Maurer, & Le Grand, 2003).

One framework for understanding the development of expert face recognition is the development of face space. One possibility is that children have fewer dimensions in their face space (Rhodes, Robbins, Jacquet, McKone, Jeffery, & Clifford, 2005). A second possibility is that children lack the ability to abstract or attend to the finer facial details coded along these dimensions (Rhodes et al., 2005), as shown by their being less sensitive to small differences amongst faces in the spacing of facial features (Freire & Lee, 2001; Mondloch et al., 2002). A third possibility is that the dimensions children use for coding faces are less relevant for discriminating amongst individuals (Rhodes et al., 2005), as shown by children's increased reliance on facial paraphernalia (e.g., glasses, hair, etc.) to recognize faces when compared to adults (Freire & Lee, 2001). The gradual development may also explain why children's face spaces have the capability of drastically changing as a result of face experience (Rhodes et al., 2005; Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005).

Changes in perceptions of facial attractiveness as a function of feature height

provide evidence that children's face prototype changes with age. Two studies that investigated facial attractiveness in 5-month-olds (Geldart, Maurer, & Henderson, 1999) and 3- to 12-year-olds (Cooper, Geldart, Mondloch, & Maurer, 2006), used faces with features placed in three different locations: high (e.g., large chin and small forehead), medium, and low (e.g., small chin and large forehead). When shown face pairs that shared the same identity, but differed in feature height, 5-month-olds looked slightly but significantly longer at faces with high-placed features (Geldart et al., 1999), whereas adults rated faces with high-placed features as least attractive. Geldart et al. (1999) suggested that both age groups preferred faces near their prototype, but that because 5-month-olds are accustomed to looking up at faces, their face prototype has a large chin and a small forehead (i.e., faces appear to have features higher on their face).

Similarly, children's ratings on facial attractiveness as a function of feature height change with age (Cooper et al., 2006). Three-year-olds with minimal peer interaction (i.e., 3-year-olds who predominantly look up at adult faces) had no preference for feature height, whereas 3-year-olds with abundant peer interactions (i.e., who interact with other children who have low-placed features) rated faces with low-placed features more attractive than faces with high-placed features. By 4-years of age, when all children engage in numerous peer interactions, children rate faces with high-placed features as least attractive, but do not rate faces with low- versus medium-placed features differently, a pattern that remains unchanged until 9-years of age. In contrast, 12-year-olds rate faces with features in the medium position more attractive than faces with low or high featural placements. Again, these results are indicative of these children's facial experience; at

puberty features move up on the face (assume a neutral/middle location) and children approach adult height.

In addition to changes in perceptions of facial attractiveness, changes in expert face recognition provide evidence that children's face prototype can change if the diet of faces to which they are exposed suddenly changes (Sangrigoli et al., 2005). Sangrigoli and de Schonen (2004a) showed that by 3-years of age children are better at recognizing faces of their own-race than faces of other races. However, if the kinds of faces that an individual is exposed to dramatically changes, i.e., if Korean children 3- to 9-years of age are adopted into Caucasian communities, their expertise for recognizing faces changes, allowing them to make finer discriminations in their new face environment (Sangrigoli et al., 2005).

In addition to their prototype changing with age, there is some evidence that children may be less sensitive than adults to how faces differ along dimensions in face space. Children are less sensitive than adults to some cues to facial identity, especially differences among faces in the spacing of features (Freire & Lee, 2001; Gilchrist & McKone, 2003; McKone, & Boyer, 2006; Mondloch et al., 2002; Mondloch & Thomson, 2008); they are less sensitive than adults to some manipulations that make faces grotesque (Mondloch et al., 2004) or distinctive (Gilchrist & McKone, 2003; McKone & Boyer, 2006); and they require larger differences among faces to systematically rate undistorted faces more attractive than faces with compressed or expanded features (Anzures et al., 2009).

Thus, despite developing slowly, children's face processing does have many adult-like characteristics. Like adults, they recognize upright faces more accurately than

inverted faces (Pellicano, & Rhodes, 2003) and own-race faces more accurately than other-race faces (Pascalis et al., 2002; Pascalis et al., 2005; Sangrigoli & de Schonen, 2004a; 2004b). Moreover, in a recent study (Nishimura et al., in press) 8-year-olds' and adults' face space was characterized by having them judge similarity for multiple face pairs. Using an odd-man-out paradigm, where participants are asked to select the face that most closely resembles a target face, Nishimura et al., demonstrated that 8-year-olds, like adults, used five dimensions to process faces. However, unlike adults, they only focused on one dimension at a time (e.g., eye colour) to make their selection while adults used multiple dimensions simultaneously. Other evidence that children's face space has some adult-like characteristics comes from two recent studies that investigated face adaptation aftereffects in 8-year-old children.

Adaptation in children. In two recent studies, simple aftereffects were used to show that children, like adults, have prototypes that are dynamically updated as a result of face experience (Anzures et al., 2009; Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008). Using a child-friendly version of the Leopold et al. (2001) paradigm (as described on page 4), in which adaptation occurred in the form of a game, 8-year-olds' recognition of previously ambiguous faces changed following adaptation. Like adults (Leopold et al., 2001; see also Andersen & Wilson, 2005), after adaptation to anti-Dan, children were more likely to assign Dan's identity to previously ambiguous faces (Nishimura et al., 2008). Likewise, following adaptation to faces with either compressed features or expanded features presented in the context of a computerized storybook, 8-year-olds' attractiveness ratings increased for faces similar to the adapting stimuli (Anzures et al., 2009). The results of both studies suggest that children's prototypes are

dynamically updated when they encounter new faces, similar to what has been shown in adults (Anderson & Wilson, 2005; Anzures et al., 2009; Bestelmeyer et al., 2008; Jaquet & Rhodes, 2008; Leopold et al., 2001; Rhodes et al., 2003; Webster & MacLin, 1999; Webster et al., 2004). These observed simple aftereffects suggest that the gradual development of face expertise is not a result of children failing to encode faces relative to a dynamic prototype. However, neither study addressed the specificity or generalization of aftereffects in children.

The purpose of the current study was to investigate the nature of children's face space using opposing aftereffects. If opposing aftereffects are elicited in children this would provide evidence that children, like adults, have multiple dissociable or independent face prototypes (Figure 3b,c), i.e., that their face space is sufficiently refined to allow them to process faces from different categories relative to different prototypes. If opposing aftereffects are not elicited in children this would provide evidence that children have one prototype (Figure 3a), i.e., that their face space is less refined than that of adults which may reflect the slow development of face expertise.

The Current Study

The method used in the current study was based on one used by Anzures et al. (2009) who demonstrated simple attractiveness aftereffects in both adults and 8-year-old children following adaptation to faces presented in the context of a storybook. Unlike other simple aftereffect studies in which adult participants look at a computer while a series of faces are flashed on a screen (Rhodes et al., 2003), adaptation occurred while participants were read a computerized story about a surprise birthday party. There were two versions of the storybook, one with only compressed Caucasian faces and the other

with only expanded Caucasian faces. Before and after being read the storybook participants were asked to rate a series of distorted children's faces on attractiveness using a 5-point rating scale. Attractiveness aftereffects were measured by calculating the difference between pre- and post-adaptation ratings to determine whether ratings increased specific to adaptation condition, e.g., whether after adaptation to expanded faces attractiveness ratings increased for expanded faces, but not for compressed or unaltered faces.

There were several methodological innovations implemented by Anzures et al. (2009) that made this task child-friendly. The first was the adaptation phase, i.e., the storybook. The second was reducing the number of attractiveness rating trials pre- and post-adaptation. Anzures et al. (2009) had their participants rate a series of five faces rather than a series of 110 faces (Rhodes et al., 2003) because children would have been unable to attend to the faces for such an extended period of time. The third was the facial distortions used. Pilot testing showed that 8-year-olds do not rate expanded or compressed faces as less attractive than undistorted faces pre-adaptation if faces are distorted by 40% or 60%, as is typical in adult studies suggesting that their face space was less refined. Consequently, their rating faces were distorted by 70% and 90% and adaptation stimuli were distorted by 90%. In the current study we modified the method used by Anzures et al. (2009) to make it appropriate for measuring opposing aftereffects. We removed half of the Caucasian faces and replaced them with Chinese faces. This modification was made so that participants could adapt to two face categories, a requirement for eliciting opposing aftereffects.

Summary of the Current Studies

The current study used opposing aftereffects to determine whether children, like adults, had category-contingent prototypes. Participants were adapted to facial distortions while being read a computerized storybook in which all of the faces from one race (e.g., Caucasian) had compressed features and all of the faces from the other race (e.g., Chinese) had expanded faces. At the beginning and the end of the storybook participants rated the normality (adults, Experiment 1a & b; 8-year-olds, Experiment 2) and/or attractiveness (8-year-olds, Experiment 2) of both Chinese and Caucasian faces that had both expanded and compressed features. Uncertainty as to which measure of opposing aftereffects was the most sensitive for children, resulted in 8-year-olds completing both normality and attractiveness rating trials.

In Experiment 1a, adults were read a story about a surprise birthday party in which both Caucasian and Chinese faces were presented on the same page. Adults were tested to determine whether the child-friendly method was sensitive to adaptation and opposing aftereffects. On each rating trial adults were presented with two versions of the same face, one with slightly expanded features (+ 10%) and one with slightly compressed features (- 10%), and asked to indicate which member of each pair looked most normal. It was hypothesized that the number of trials on which participants selected the face with expanded features would not differ for the two face races pre-adaptation, but that post-adaptation the number of trials on which they selected the expanded version would be higher for the face race that had expanded features during adaptation than for the face race that had compressed features during adaptation. The lack of opposing aftereffects elicited by this method led to the creation of a new storybook used in Experiment 1b.

In Experiment 1b, adults were read a story about two birthday parties, one party with only Caucasian guests and the other party with only Chinese guests. Adults were again shown face pairs with facial distortions of + 10% and - 10% and were asked to indicate which member of each pair looked the most normal. Caucasian and Chinese faces were presented on separate and alternating pages, similar to how stimuli are presented in adult opposing aftereffect studies (Jaquet et al., 2008; Little et al., 2008; Rhodes et al., 2004).

In Experiment 2, 8-year-olds were tested to determine whether, like adults, they formed dissociable face categories. Two sets of test trials were administered to 8-year-old children. On the first set of trials children rated the attractiveness of distorted and undistorted faces, replicating the method used in the one previous study showing attractiveness aftereffects in children (Anzures et al., 2009). Both pre- and post-adaptation, children were shown six individual faces (three Caucasian and three Chinese). For each face race one face had compressed features (- 70%), one had expanded features (+ 70%), and one face was undistorted. Children were asked to rate each face on a 5-point attractiveness scale. It was hypothesized that children would rate the undistorted faces as most attractive pre-adaptation with no difference between faces with compressed versus expanded features. It was hypothesized that post-adaptation ratings of expanded faces would increase for the face race that had expanded features during adaptation whereas ratings of compressed faces would increase for the face race that had compressed features during adaptation.

On the second set of trials children were shown two versions of the same face and asked to indicate which member of each pair looked more normal. This task was

designed to be similar to that administered to adults in Experiment 1b. Unlike adults, 8-year-olds were shown one undistorted version paired with a version that had either compressed (- 50%) or expanded (+ 50%) features. These face pairs were based on a previous study investigating simple aftereffects in 5-year-old children (Mondloch, Hatry, & Short, 2009). It was hypothesized that children would select the undistorted face as most normal pre-adaptation, that the number of expanded faces selected would increase in the face race that was expanded during adaptation but that the number of compressed faces selected would increase in the face race that was compressed during adaptation.

Experiment 1a

The purpose of Experiment 1a was to determine whether a modified version of the child-friendly task Anzures et al. (2009) used to measure simple attractiveness aftereffects in adults and 8-year-olds would elicit opposing aftereffects in adults. Adults were adapted to Caucasian and Chinese faces that were distorted in opposite directions. Faces were presented in the context of a storybook about a surprise birthday party. Opposing aftereffects were measured by asking adults to indicate which member of several face pairs was most normal both pre- and post-adaptation; one member of each pair had expanded features and the other member of each pair had compressed features. The decision to measure face normality was made as a result of Winkler and Rhodes' (2005) findings, which demonstrated that rating normality was a more consistent and sensitive measure for detecting perceptual changes across individuals when compared to attractiveness ratings following adaptation to distorted bodies (e.g., compressed or expanded). In addition normality ratings are commonly used for measuring opposing aftereffects in other adult studies (Little et al., 2005; Little et al., 2008; Rhodes et al.,

2004). We measured the number of expanded face selected pre- and post-adaptation separately for the race of face that was expanded during adaptation and the race of face that was compressed.

Simple aftereffects are typically measured by calculating the difference between pre- and post-adaptation ratings; aftereffects are evident if ratings for faces that match the adapting stimuli increase and faces that are unaltered and oppositely distorted decrease or remain unchanged (Rhodes, et al., 2003). Opposing aftereffects are usually smaller than simple aftereffects (Jaquet & Rhodes, 2008), possibly a result of shared neural coding mechanisms (refer to Model C, page 11). Thus, when analyzing the pre- to post-adaptation differences for each face category, opposing aftereffects may be masked as a result of the measure being too rigorous (refer to Bestelmeyer, et al., 2008). Therefore, an alternative method for analyzing opposing aftereffects is to measure the difference between post-adaptation ratings between the two adapting conditions (i.e., between the two face categories). Although a comparison between pre- to post-adaptation measures is typically performed, pre-adaptation ratings are important to determine whether there were trends for ratings of one face category to increase and for ratings of the other face category to decrease (refer to Jaquet & Rhodes, 2008). It is this second approach that I used in my research.

Opposing aftereffects would be evident if adults selected the expanded member of each pair post-adaptation more often for the race of face that was expanded during adaptation than for the race of face that was compressed. No differences were expected pre-adaptation. Although the strongest evidence for opposing aftereffects would be an increase in the number of expanded faces selected post-adaptation for the race of face that

was expanded during adaptation and a concurrent decrease in the number of expanded faces selected post-adaptation for the race of face that was compressed, our child-friendly method allowed only five trials per race pre- and post-adaptation. Consequently we conducted an informal analysis of changes within each adaptation condition (i.e., compressed versus expanded) but conducted statistical analysis directly comparing the two adaptation conditions pre- and post-adaptation. Evidence of opposing aftereffects would indicate that the method is suitable for investigating whether children demonstrate opposing aftereffects.

Method

Participants

Twenty-four undergraduate students (21 female; M age = 19.6 years, range = 18-24) participated. All participants were Caucasian and received partial course credit or a small honorarium. An additional seven adults were tested but were excluded from the final analyses because they did not meet the pre-adaptation criteria (see procedure, $n = 5$), or could not correctly identify storybook characters post-adaptation ($n = 2$); failure to meet any one of these exclusion criteria suggests an unusual insensitivity to facial distortions, a failure to understand the task, or a lack of attention.

Stimuli

The adaptation procedure consisted of three phases. In all three phases, the colored photographs presented were of 4- to 6-year-old children. In the pre-adaptation phase, adults viewed 10 face pairs (five Caucasian and five Chinese). The two members of each face pair shared the same identity, but one member had compressed features and the other member had expanded features. In the adaptation phase adults were shown a series of Caucasian and Chinese faces; all faces from one race (e.g., Caucasian) were

compressed and all faces from the other race (i.e., Chinese) were expanded. In the post-adaptation phase 10 additional face pairs (five Caucasian) were viewed. All facial distortions were made using the spherize function in Adobe Photoshop. First, for each face, the internal features were selected using the lasso tool. Next the spherize function was selected and then the band-aid function was selected to blend the skin.

Face stimuli were selected using measures of perceived facial distinctiveness and facial normality. Twelve Brock University graduate students were shown a series of 40 colored photographs of 4- to 6-year children (20 Caucasian; 20 female). Distinctiveness ratings were made using a 5-point scale; 5 meant “very distinctive” and 1 meant “not at all distinctive.” Facial distinctiveness was defined as “the degree each face would stick out in a crowd.” In addition to distinctiveness ratings, 12 different Brock students were shown face pairs and were asked to select the more normal looking face. Each pair was comprised of two faces of the same identity but one member had compressed features (-10%) and the other had expanded features (+10%). Faces selected for pre- and post-adaptation trials were made using facial distinctiveness and face normality measures. The criteria for face selection was that each face had a maximum of one very distinctive rating (5), a mean distinctiveness rating less than three and an equal probability of being selected as more normal looking when expanded and compressed. Adaptation faces for the storybook were selected using distinctiveness ratings in which each original (i.e., undistorted) face only had one very distinctive rating (5) and a mean distinctiveness rating that was less than four.

Similar to Anzures et al. (2009), all of the faces were presented in the form of a computerized storybook about a birthday party. A Canon Powershot digital camera was

used to take pictures of colored drawings on a 14 x 22 inch background. The drawings were used as the background and the distorted faces were superimposed onto the hand-drawn pictures, which comprised the pages of the storybook.

At the beginning of the experiment participants' sensitivity to facial distortions was tested. The criterion trials consisted of four face pairs (two Caucasian) with larger distortion levels ($\pm 20\%$). Each pair was comprised of two faces of the same identity but one face was distorted (compressed or expanded) and the other face was undistorted. For each race, participants viewed one pair with a compressed distortion and one pair with an expanded distortion. Participants were required to select the undistorted face on three of the four criterion trials in order to be included in the final analyses. Failure to meet this criterion might indicate an unusual insensitivity to facial distortions, a failure to understand the task, or a lack of attention.

The adapting stimuli consisted of 12 colored photographs of children's faces (six Caucasian and six Chinese); for each race, three faces were female. Faces were presented in the context of a storybook about a surprise birthday (see Figure 4d). Caucasian and Chinese guests attended the party. Faces within the storybook were distorted by $\pm 60\%$. The level of distortion for adapting faces was selected based on previous work done by Jaquet, et al. (2007) and Anzures et al. (2009). One version of the storybook consisted of compressed (-) Caucasian and expanded (+) Chinese faces; the other version consisted of expanded (+) Caucasian and compressed (-) Chinese faces. Two versions of the storybook were used to control for differences in normality judgments as a function of race or facial distortions (e.g., expanded and compressed). The size of adapting stimuli

varied to eliminate low-level retinotopic adaptation and to allow us to present the faces in the context of a storybook.

The rating stimuli consisted of 20 face pairs (10 Caucasian), as shown in Figure 4a. Participants were asked to indicate which member of each pair was most normal both pre- and post-adaptation in order to determine the magnitude of adaptation. The presentation of face pairs and the degree of distortion used was made following considerable adult pilot testing ($n = 96$) and an extensive literature review. As a result this method is similar to other studies shown to be sensitive for measuring opposing aftereffects in adults (Bestelmeyer et al., 2008; Jaquet et al., 2007; Little et al., 2005; Little et al. 2008). Each face pair consisted of two versions of the same identity; one member had compressed ($- 10\%$) features and the other member had expanded ($+ 10\%$) features (see Jaquet et al., 2007).³ We divided the face pairs into two sets of 10 pairs; half of the face pairs in each set were Caucasian and half were Chinese. For each face set, participants viewed three pairs of male faces and two pairs of female faces for one race and three pairs of female faces and two pairs of male faces for the other; the relative number of male versus female faces for each race was counterbalanced across the two face sets. Face pairs from one set were shown pre-adaptation and faces from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants and within each set faces appeared in one of two different orders.

The number of rating stimuli used (10 pre-adaptation) was fewer than those typically used in adult opposing aftereffect studies (48 stimuli pre-adaptation; Jaquet et al., 2008) because we wanted to use a task that was suitable for testing children, which

meant keeping the rating trials to a minimum. Anzures et al. (2009) demonstrated simple aftereffects with only five trials pre- and post-adaptation. Because our participants were adapted to two different races with opposing facial distortions the overall number of trials was doubled.

Following post-adaptation trials, participants completed a memory task that was used to verify that participants had been attending to the characters during adaptation and to determine whether memory for own-race faces was more accurate than memory for other-race faces. They were shown four face arrays, each of which was comprised of six faces. Of the six faces, three were familiar storybook characters and three were novel faces. All of the faces within an array were matched for race and sex and they had the same distortion presented during the adaptation phase for that race ($\pm 60\%$). To eliminate any biases, the order of array presentation and the location of faces within an array were counterbalanced across participants.

Procedure

The procedure received clearance from the Research Ethics Board at Brock University. Adults provided informed consent and were then asked to sit 60cm away from a 23-inch computer monitor. Similar to Anzures et al.'s (2009) study, participants were asked to look at pictures on the monitor as they were read a story. On the first page, participants were informed that they were going to attend a surprise birthday party. Participants were told that they were about to see pairs of brothers and sisters and that they would be asked to decide which brother or which sister from each pair appeared more normal looking. Participants indicated their choice by raising either their right or left hand. One member of each pair was undistorted and the other had either compressed

or expanded features. As these were the criterion trials, participants needed to select three out of the four undistorted faces as more normal looking to be included in the final sample. Five adults were excluded because they failed to select three out of the four undistorted faces.

After the criterion trials, participants were told that they would be meeting brothers and sisters who were going to the surprise party and were again asked to select the more normal looking sibling. Participants were informed that the faces they were about to see were not of real children and it was OK if they thought one face was more normal looking than the other. Participants viewed 10 face pairs (five Caucasian) and each face within a pair was distorted by $\pm 10\%$. The order of face presentation was constrained by race and gender: Face pairs alternated by race and no more than two pairs of the same gender were shown consecutively. Two different face-pair orders were shown pre- and post-adaptation to eliminate order effects. Pre-adaptation ratings provided a baseline measure of individuals' normality judgments; we did not expect the number of expanded faces selected to differ for Caucasian versus Chinese faces. Once the 10 face pairs were presented, participants were asked to look at pictures on the computer monitor while a 6-minute story was read to them. The primary purpose of the storybook was to adapt participants to Caucasian and Chinese faces that were distorted in opposite directions. The storybook was designed to capture children's attention and keep them focused on the pictures (i.e., the adapting stimuli) on the computer monitor. Throughout the story participants were asked questions pertaining to the whereabouts of the birthday boy to ensure that they maintained their focus on the pictures. The storybook consisted of 20 pages with illustrations that had superimposed photographs of the children's faces.

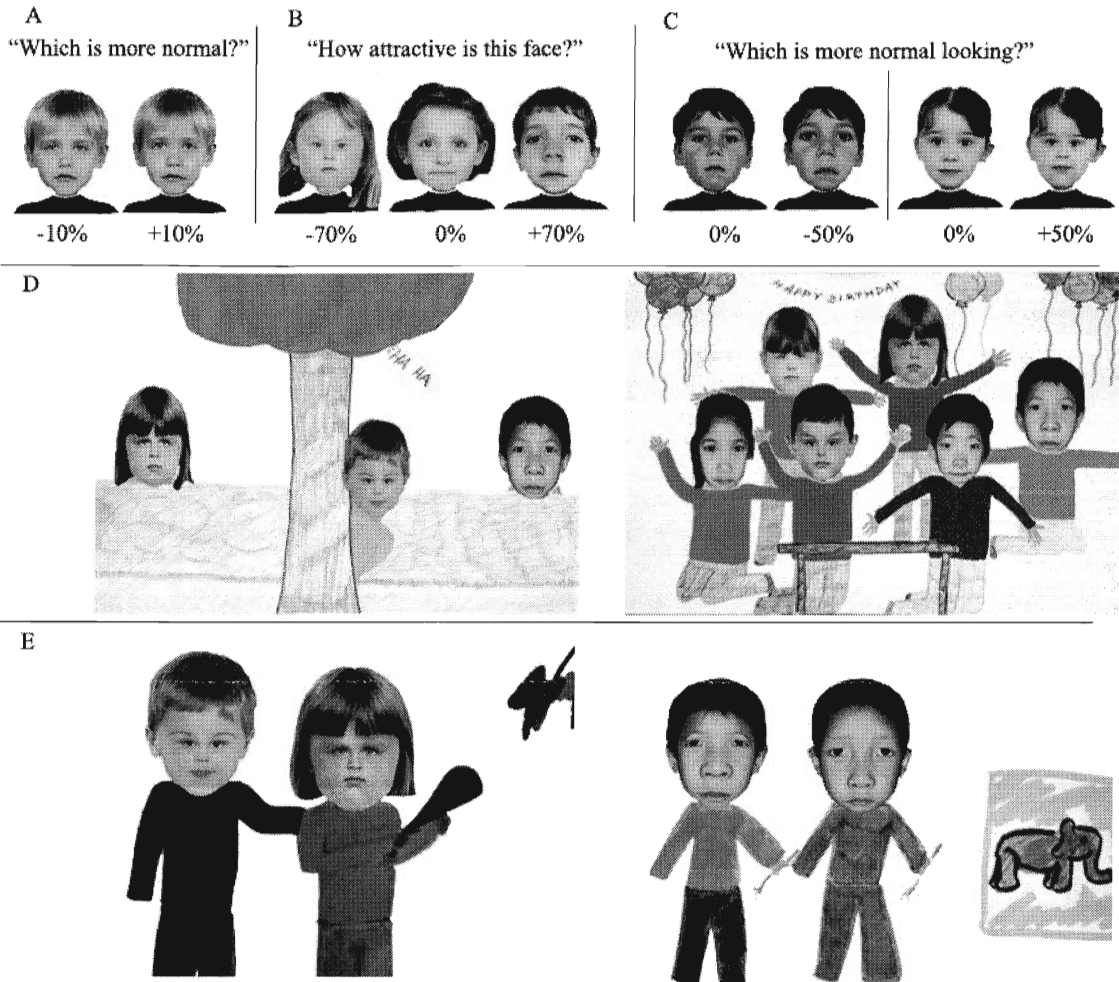


Figure 4. A-C: Stimuli presented during the rating phase. Adults were asked to indicate which member of each pair was more normal (A). Children were asked to rate the attractiveness of each point on a 5-point scale (B) and then to indicate which member of each pair was more normal (C). Sample pages from Experiment 1a's storybook (D) and from Experiment 1b's storybook (E) are shown. In both of these storybooks participants were adapted to the version that presented compressed Caucasian faces (- 60%) and expanded Chinese faces (+ 60%).

During the story participants were introduced to 12 storybook characters (six Caucasian and six Chinese) and saw faces of each race 20 times over the course of the story. The number of faces shown on each page varied. Some pages displayed only one face whereas others had as many as seven faces. In addition, some of the pages showed faces of only one race while other pages showed both Caucasian and Chinese faces. Half the participants viewed compressed Caucasian faces and expanded Chinese faces while the other half viewed expanded Caucasian faces and compressed Chinese faces.

At the end of the 6-minute story, post-adaptation trials occurred. In the storybook new guests begin to arrive just as the birthday boy is about to open his presents. Participants again were asked to choose which sibling looked more normal. These trials differed from the pre-adaptation trials in that face pairs were presented for 3 seconds and then replaced by a blank slide. Following each response, participants were given additional adaptation “top-up” in order to maintain the adaptation. Adaptation “top-up” involved the sequential presentation of two different storybook characters (one of each race). The top-up presentation order was constrained such that the first face matched the race of the last face pair (e.g., Chinese) and the second matched the race of the face pair to be shown next (i.e., Caucasian). The brief presentation and adaptation top-up were performed to maintain face adaptation (see Jaquet et al., 2007; Rhodes et al., 2004).

The memory task followed the post-adaptation trials. Participants were asked to hand out loot-bags to the girls and boys who attended the party. They were shown four different face arrays; for each race there was one male and one female array. For the male face arrays participants were first asked to select the three boys who attended the party by either pointing to the faces or by saying the number located beside each face. For the

female face arrays participants were asked to identify the three girls who attended the party.

Results

Normality Trials

For each participant the number of trials on which they selected the expanded face as most normal was calculated for each race (the to-be-expanded race and the to-be-compressed race) pre- and post-adaptation. A 2 (adaptation condition: expanded and compressed) x 2 (time: pre-adaptation and post-adaptation) repeated measures ANOVA was conducted to determine whether the number of expanded faces chosen changed as a function of adaptation. It was hypothesized that the number of expanded faces selected would not differ as a function of adaptation condition pre-adaptation, but that post-adaptation the number of expanded faces selected would be higher for the race of face that was expanded during adaptation (e.g., Chinese) than for the race of face that was compressed (i.e., Caucasian). Race was not included as a factor in the ANOVA; each adapting condition consisted of ratings from both Caucasian (for half of the participants) and Chinese faces (for the other half of participants).

Neither the main effect of adaptation condition nor the main effect of time was significant, $ps > 0.10$ and there was no two-way interaction, $F(1, 23) = 1.91, p > 0.10$. As shown in Figure 5, adults did not show opposing aftereffects. The selection of face normality did not change in a manner specific to adaptation. The number of expanded faces selected as most normal looking post-adaptation was not significantly higher for the race that was expanded during adaptation ($M = 2.71, SE = .32$) than for the race that was compressed during adaptation ($M = 2.38, SE = .32$), $t(23) = -.87, p > .40$ (two-tailed).

Memory Trials

A two-tailed t-test was performed to determine whether identification accuracy differed as a function of race. Participants identified Caucasian storybook characters more accurately (M correct = 5.25, SE = .15) than Chinese storybook characters (M correct = 4.75, SE = .16), $t(23) = 2.14$, $p < .05$. These results indicate that there was an own-race advantage when identifying party guests.

Discussion

Our results indicate that our child-friendly method did not elicit opposing aftereffects in adults. Adults did not select faces with distortions consistent with those presented during adaptation as more normal looking post-adaptation (i.e., they did not select more expanded faces post-adaptation for the race of face that was expanded during adaptation than the race of face that was compressed). The lack of opposing aftereffects in our study is somewhat surprising given that our task had many characteristics in common with tasks used in previous studies. We used a modified version of a storybook that successfully elicited simple attractiveness aftereffects in adults in a previous study (Anzures et al., 2009). The story itself was the same and the degree of facial distortion of the adaptation stimuli ($\pm 60\%$) was identical both to a previous study (Anzures et al., 2009) and to other studies demonstrating opposing aftereffects in adults (Jaquet et al., 2007; Jaquet et al., 2008). One possibility is that replacing half of the Caucasian faces in our initial storybook with Chinese faces resulted in inadequate exposure to the adaptation stimuli. This explanation is unlikely however, because it took 6 minutes to read our storybook and several opposing aftereffect studies have used an adaptation period of only 2 minutes (Jaquet et al., 2007; Jaquet et al., 2008; Rhodes, et al., 2004). A second

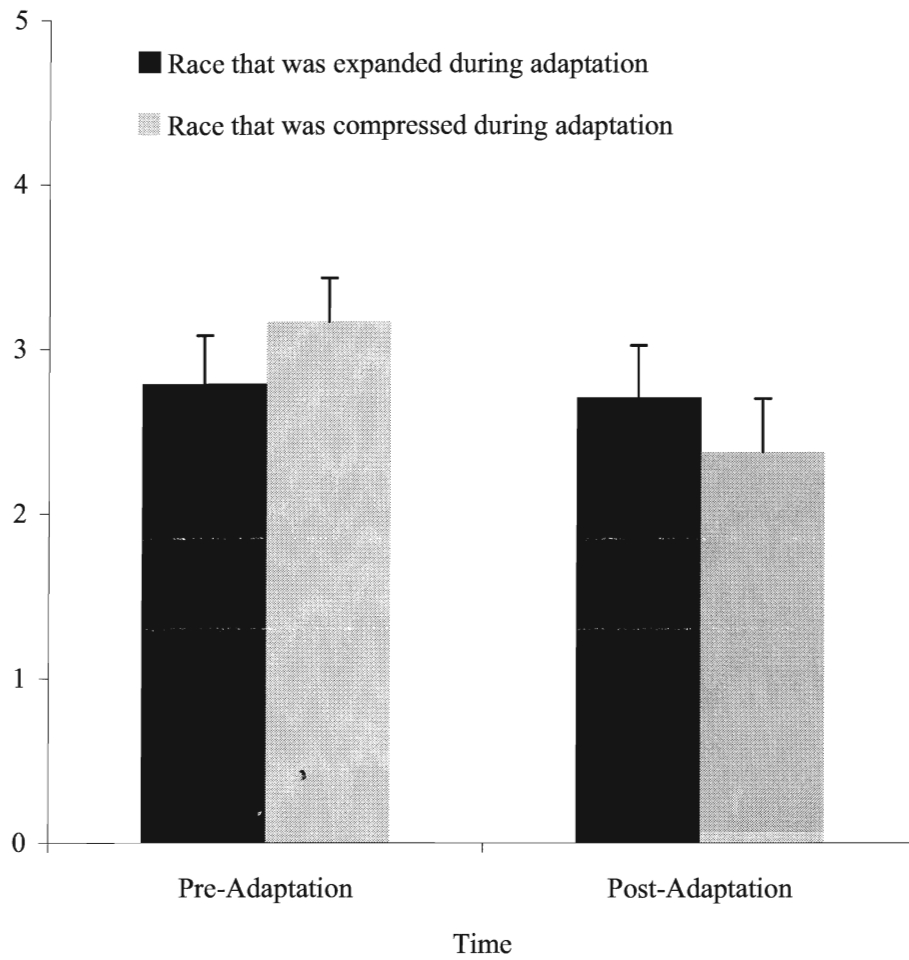


Figure 5. Experiment 1a: Out of five trials, the mean number (+1 se) in which the expanded (+10) face was selected as more normal by adults pre- and post-adaptation. Standard error bars represented the standard error of the mean from each condition.

possibility is that the measurement used in the current study (two-alternative forced choice) is less sensitive than the attractiveness ratings used in our previous study (Anzures et al., 2009). This explanation also is unlikely because several published studies have used our current method successfully (Jaquet et al., 2007; Little et al., 2005; Little et al., 2008).

We also used similar methods previously shown to be effective in eliciting opposing aftereffects in adults (Jaquet et al., 2007; Jaquet et al., 2008; Little et al., 2005; Little et al., 2008; Rhodes et al., 2004). Like other opposing aftereffect studies (Jaquet et al., 2007; Jaquet et al., 2008; Little et al., 2005; Little et al., 2008), our participants were asked to complete a two-alternative forced choice task both pre- and post-adaptation. Lastly, our adaptation top-up was based on previous studies and thus is known to be successful in maintaining adaptation while measuring opposing aftereffects (Jaquet et al., 2007; Rhodes et al., 2004).

An intriguing possibility is that presenting Caucasian and Chinese faces in the context of an integrated birthday party reduced the salience of race as a perceptual or social category. Both Bestelmeyer et al. (2008) and Jaquet et al. (2007) have reported that for opposing aftereffects to occur, faces need to be categorized into two distinct categories. Whereas opposing aftereffects are observed when Caucasian and Chinese faces are distorted in opposite directions, opposing aftereffects are not observed when Chinese and 'super-Chinese' faces are distorted in opposite directions (Jaquet et al., 2007), presumably because Chinese and super-Chinese faces belong to the same category. In the current storybook Caucasian and Chinese children were portrayed as friends attending the same birthday party and were shown together on several pages. In

Experiment 1b, we tested the possibility that we had inadvertently reduced the salience of face race. We measured opposing aftereffects using a modified version of the storybook in which Caucasian and Chinese children attended separate birthday parties.

Experiment 1b.

Unlike the storybook used in Experiment 1a, in which both Caucasian and Chinese guests attended one birthday party, in the storybook used in Experiment 1b, Caucasian and Chinese children attend separate birthday parties. A central character, Calvin, moves back-and-forth between the two parties throughout the storybook. Thus on alternate pages participants view Chinese faces distorted in one direction (e.g., compressed) and Caucasian faces distorted in the opposite direction (i.e., expanded). This new storybook was designed to increase the salience of face race as a category.

Method

Participants

Twenty-four undergraduate students (20 female; M age = 21.5 years, range = 18-27) participated. All participants were Caucasian and received partial course credit or a small honorarium. An additional nine adults were tested but were excluded from the final analyses because they did not meet the pre-adaptation criteria (see procedure, $n = 6$), did not follow instructions ($n = 1$) or could not correctly identify storybook characters post-adaptation ($n = 2$); failure to meet any one of these exclusion criteria suggests an unusual insensitivity to facial distortions, a failure to understand the task, or a lack of attention.

Stimuli & Procedure

The procedure and stimuli used were exactly the same as those used in Experiment 1a, except for the adaptation phase. The adapting stimuli were the same as

those used in Experiment 1a, except that they were presented in a different storybook that had two different versions. One version of the storybook consisted of compressed (-) Caucasian and expanded (+) Chinese faces; the other version consisted of expanded (+) Caucasian and compressed (-) Chinese faces. Faces within the storybook were distorted by $\pm 60\%$. The adapting stimuli were presented in the context of a storybook about two birthday parties. All of the guests at one party were Caucasian and all of the guests at the other party were Chinese. On any given page only one party was depicted (i.e., only one race was shown). The storybook consisted of 20 pages, in which race alternated from page to page. During the story participants were introduced to 12 storybook characters. Six characters attended each party and participants viewed one to six characters at a time. As in Experiment 1a, participants saw a total of 20 Caucasian and 20 Chinese faces.

Results

Normality Trials

For each participant the number of trials on which they selected the expanded face as most normal was calculated for each race pre- and post-adaptation. Like Experiment 1a, a 2 (adaptation condition: expanded and compressed) x 2 (time: pre-adaptation and post-adaptation) repeated measures ANOVA was conducted to determine whether the number of expanded faces chosen as most normal changed as a function of adaptation. It was hypothesized that the number of expanded faces selected would not differ as a function of face race pre-adaptation, but that the number of expanded faces selected would be higher for the race of face that was expanded during adaptation (e.g., Chinese) than for the race of face that was compressed (i.e., Caucasian). Race was not included as

a factor in the ANOVA; each adapting condition consisted of ratings from both Caucasian (for half of the participants) and Chinese faces.

Neither the main effect of adaptation condition nor the main effect of time was significant, $ps > 0.10$. The ANOVA revealed a significant two-way interaction, $F(1, 23) = 4.11, p = .05$. As shown in Figure 6, there was a trend for the number of expanded faces selected to increase for the race of face that was expanded during adaptation and decrease for the race of face that was compressed. Although two-tailed paired t-tests revealed that the change in the number of expanded faces selected did not differ pre- versus post-adaptation for either adaptation condition (race that was expanded, $t(23) = 1.11, p > .20$; race that was compressed, $t(23) = .1.74, p > .09$), post-adaptation participants selected more expanded faces for the face race that was expanded during adaptation ($M = 2.71, SE = .24$) than they did for the face race that was compressed during adaptation ($M = 1.92, SE = .21$), $t(23) = 2.31, p < .05$. As predicted, there was no significant difference between the number of expanded faces chosen as most normal looking pre-adaptation, $p > .50$. Similar conclusions could be made for the selection of compressed faces by taking the inverse of the means for the expanded faces.

Memory Trials

A two-tailed t-test was performed to determine whether identification accuracy differed as a function of race. Participants identified Caucasian storybook characters more accurately ($M_{\text{correct}} = 5.68, SE = .15$) than Chinese storybook characters ($M_{\text{correct}} = 4.36, SE = .17$), $t(18) = 6.83, p < .0001$. These results indicate that there was an own-race advantage when identifying party guests.

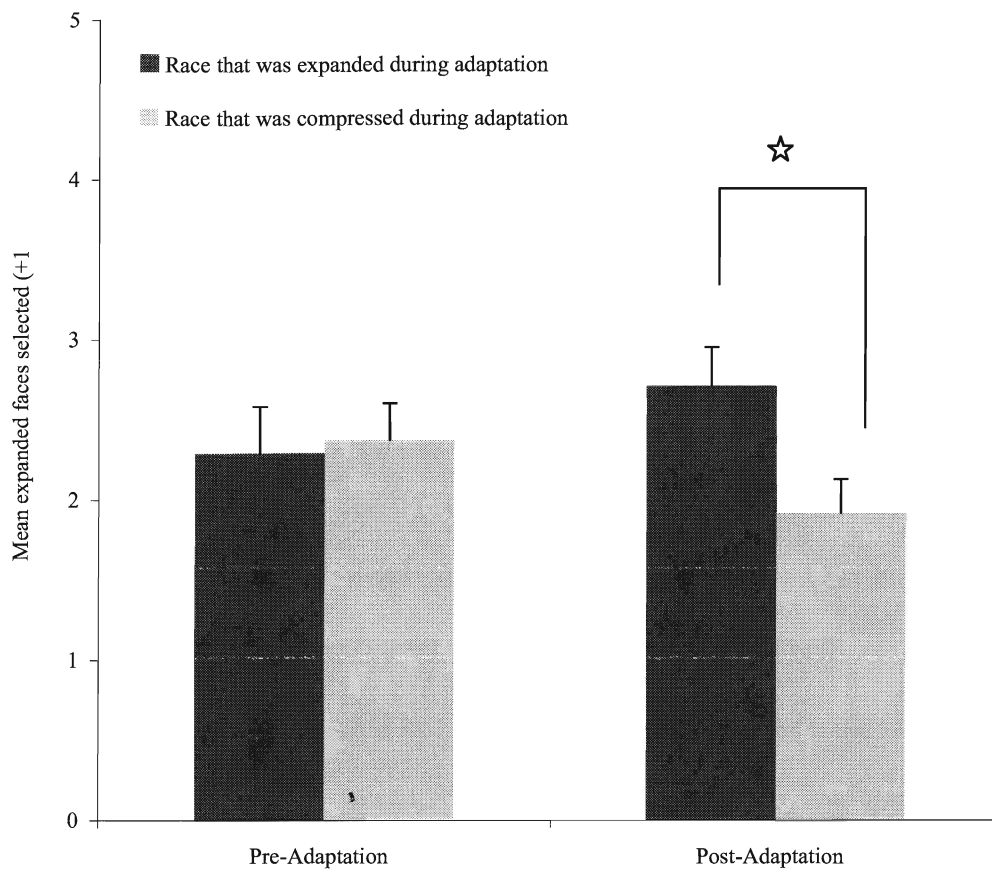


Figure 6. Experiment 1b: Out of five trials, the number in which the expanded (+ 10%) face was selected as more normal by adults pre- and post-adaptation. *Indicates a significant difference between the number of times the expanded faces was selected for the face race that was expanded during adaptation (black bar) versus the face race that was compressed during adaptation (grey bar), $p < .05$. Standard error bars represent the standard error for the mean from each condition.

Discussion

Adults showed a pattern of results consistent with opposing aftereffects; their selection of the most normal face post-adaptation was specific to adaptation condition. For example, after adaptation adults were more likely to select the expanded member of each pair for the race of face that was expanded during adaptation than the race of face that was compressed. These results are consistent with the hypothesis that for opposing aftereffects to be elicited faces distorted in opposite directions must belong to two face categories, as previously suggested by Bestelmeyer (2008) and Jaquet et al. (2007); this pattern of results suggests that there is a prototype for each face category but that we do not have distinct prototypes within a face category. The results of Experiments 1a and 1b are particularly striking because unlike Bestelmeyer and Jaquet who created novel face categories (e.g., hyper-female, super-Chinese), we used pre-existing categories (i.e., Caucasian and Chinese). The implications of these findings are discussed more fully in the General Discussion.

The success of Experiment 1b indicates that we have developed a child-friendly task that is sensitive to opposing aftereffects. In Experiment 2 we further modified the pre- and post-adaptation trials and investigated whether 8-year-old children would show opposing aftereffects using the segregated storybook.

Experiment 2

The purpose of Experiment 2 was to determine whether 8-year-olds, like adults, would show opposing aftereffects. There have been only two previous studies investigating whether children's prototypes behave in a similar manner to those of adults. In one study identity aftereffects were examined (Nishimura et al., 2008) and in the other,

the focus was on simple attractiveness aftereffects (Anzures et al., 2009). In both cases, results indicated that children have face prototypes that are dynamically updated as a result of face experience. What we wanted to know was whether children have category-contingent prototypes.

In Experiment 1b, opposing aftereffects were measured using a two-alternative forced choice task, in which adults were asked to select the more normal looking of two faces that were distorted in opposite directions but that shared the same identity. Following considerable pilot testing of 8-year-olds ($n = 14$) and an extensive literature review, changes were made to the measurement of opposing aftereffects in 8-year-olds. Pilot testing revealed that children were unable to perform the two-alternative forced choice task that adults completed. Uncertainty over which face presentation style (e.g., individual or face pair) and which measurement (e.g., attractiveness or normality) was the most sensitive for children led us to use both presentation styles and both measurements. Similar to the successful measurement of attractiveness aftereffects in children by Anzures et al. (2009), our 8-year-olds were first shown and asked to rate a series of distorted faces on a 5-point attractiveness scale. Unlike Anzures et al. (2009) our 8-year-olds rated unaltered and $\pm 70\%$ faces, but did not rate $\pm 90\%$ faces. This was because our participants had to rate both Caucasian and Chinese faces and we did not want to double the number of trials. The ratings of $\pm 90\%$ faces did not alter the pattern of results reported by Anzures et al. (2009), and so eliminating these trials was unlikely to have an impact on our findings.

To include a measure of opposing aftereffects similar to that used when testing adults (Experiment 1b), following the attractiveness ratings, 8-year-olds were shown face

pairs and were asked to select the more normal looking face. Unlike Experiment 1b in which we presented pairs of faces with two opposing facial distortions ($\pm 10\%$), 8-year-olds were shown pairs of faces that were comprised of an unaltered face paired with either a $- 50\%$ or $+ 50\%$ distortion. This method was used because extensive pilot testing revealed that pre-adaptation, when children were shown face pairs that shared the same identity but differed in distortion (one face was compressed by 20% and the other was expanded by 20%) and were asked to pick which member of each pair was more normal, individual children selected the same distortion on almost every trial (in contrast to adults who performed at chance levels). Presenting one unaltered and one distorted version of each face was based on a previous method that successfully elicited simple attractiveness aftereffects in 5-year-olds (Mondloch, et al., 2009). In addition to modifying the testing protocol, we increased the level of facial distortion during the adaptation phase. Unlike adults, who were adapted to faces distorted by $\pm 60\%$, 8-year-olds were adapted to faces that were distorted by $\pm 90\%$. This difference in degree of distortion was used because Anzures et al. (2009) had previously shown that pre-adaptation, 8-year-old children did not consistently rate faces distorted by 40% and 60% as less attractive than their unaltered versions. Consequently, Anzures et al. used adapting faces that were distorted by $\pm 90\%$, and rating faces that were distorted by $\pm 70\%$ and $\pm 90\%$.

If 8-year-old children, like adults, have category-contingent face prototypes then we would expect to find opposing aftereffects for both attractiveness ratings and normality judgments. Opposing aftereffects would be evident if attractiveness ratings post-adaptation were influenced by adaptation condition. For example, after adaptation to expanded Caucasian faces and compressed Chinese faces, opposing aftereffects would be

evident if attractiveness ratings for expanded Caucasian faces and compressed Chinese faces increased post-adaptation, while attractiveness ratings for the other facial distortions remained the same or decreased. Similarly, opposing aftereffects would be evident if the selection of the most normal face post-adaptation was specific to adaptation condition. Prior to adaptation we expected children to select the undistorted member of each pair. Opposing aftereffects would then be evident if children selected faces consistent with adaptation stimuli post-adaptation. For example, following adaptation to expanded Caucasian faces and compressed Chinese faces, opposing aftereffects would be evident if 8-year-olds selected an expanded Caucasian face as more normal looking than an undistorted Caucasian face but a compressed Chinese face as more normal looking than an undistorted Chinese face. Overall, these results would suggest that 8-year-olds do show opposing aftereffects for race and that, like adults, they have category contingent prototypes, at least for race of face.

Method

Participants

Twenty-four Caucasian 8-year-olds (± 6 months; 12 females) participated. Before testing, the 8-year-olds' parents provided written informed consent and the child provided verbal assent. Three additional children were tested but excluded from data analysis because they did not pass the pre-adaptation criteria ($n = 2$; see procedure) or because every face pre- and post-test was given the same rating ($n = 1$).

Stimuli

Like adults, the procedure for 8-year-olds consisted of three phases. The faces used as stimuli were the same for both adults and 8-year-olds.

The primary method used to measure opposing aftereffects in children was attractiveness ratings (see Anzures et al., 2009). The rating stimuli consisted of 12 individual faces that were divided into two sets of six (three Caucasian faces per set). As shown in Figure 4b, a face set consisted of one undistorted, one compressed (-70%), and one expanded ($+70\%$) face for each race. Faces from one set were shown pre-adaptation and faces from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants and within each set faces appeared in one of two different orders. Race of face alternated across trials and gender was counterbalanced across pre-and post-trials within each race (i.e., if two female Caucasian faces and one male Chinese face were shown pre-adaptation then one female Caucasian face and two male Chinese faces were shown post-adaptation). This manipulation was made to control for any effect order of face presentation may have on attractiveness ratings. It was expected that participants would rate the undistorted faces of both races as most attractive pre-adaptation; opposing aftereffects would be evident if attractiveness ratings increased for faces with a similar distortion (e.g., expanded or compressed) and race as that of the adapting stimuli post-adaptation.

The secondary method used to measure opposing aftereffects was normality ratings. The rating stimuli consisted of eight face pairs that were divided into two sets of four, with two Caucasian pairs within each set. Faces from one set were shown pre-adaptation and faces from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants and within each set the faces appeared in one of two different orders. As shown in Figure 4c, the two members of each pair shared the same facial identity, but one member of each pair was

undistorted and the other member had either compressed (- 50%) or expanded (+ 50%) features. It was expected that children would almost exclusively select undistorted faces as most normal pre-adaptation but that their preferences would shift in the direction of adaptation post-adaptation. These trials were based on unpublished data showing simple attractiveness aftereffects in 5-year-old children. In that study children were shown two faces with the same identity; one face was unaltered and the other face was distorted by either - 70% or + 70%. Children were asked to choose the prettier face from each pair (Mondloch, et al., 2009).

The same faces were shown to children during adaptation that were shown to adults; however, for children the distortions were much larger ($\pm 90\%$) to ensure that the level of distortion seen during adaptation exceeded that of the rating stimuli (see Anzures et al., 2009). Having to use larger distortions is not surprising because children are less sensitive than adults to some facial distortions (Mondloch, et al., 2004).

Procedure

The task began by introducing children to a 5-point cup-rating scale. Each child was asked to rate food that they really liked and food that they really disliked using the cups (see Anzures et al., 2009). To ensure that children understood the scale, they then completed two sets of three criterion trials. In the first set of trials, children were first simultaneously shown three presents that varied in attractiveness and were then shown each present individually. Children rated each present using the 5-point cup-rating scale in which the largest cup meant 'very, very pretty' and the smallest cup meant 'not at all pretty'. In the second set of criteria trials, children rated three balloons using the same protocol. Participants were excluded from all analyses if they made more than one

reversal, defined as rating a less attractive item (e.g., a paper bag) as more attractive than the next most attractive item (i.e. a green present with polka dots). They also were excluded if they rated the least attractive item as most attractive (e.g., the paper bag as more attractive than the green present and blue present with bows and streamers). Exclusion was based on the assumption that the participant was not being attentive or not using the rating scale consistently.

Children then were told that they were going to meet some guests who were going to one of the two parties. They were shown six guests (three Caucasian) from each party and were asked to use the 5-point cup scale to rate each face on attractiveness. Each face remained on the computer until the child provided a rating. Like adults, children were told that these were not pictures of real children and so it was OK if they thought some of them were not at all attractive. Both pre- and post-adaptation the two undistorted faces for each race were presented first and at most two faces of the same sex or race were shown consecutively thereafter.

After completing the attractiveness ratings, children were then told that they would see pairs of brothers and sisters and that their job was to show the experimenter which brother/sister of each pair looked more normal. Each child viewed four face pairs (two Caucasian); each face pair was comprised of one undistorted face and either a compressed version of that same face (one trial per face race) or an expanded version of that same face (one trial per face race). Again, faces remained on the screen until the child made a choice (by raising their left or right hand) and they were reminded that these were not pictures of real children. For the normality rating trials, the first two pairs shown matched the adapting conditions (e.g., for children adapted to compressed Caucasian and

expanded Chinese faces, the first face pairs presented included a compressed Caucasian face and an expanded Chinese face). Which race was presented first was counterbalanced across participants.

Post-adaptation trials were identical to pre-adaptation trials with two exceptions: faces only remained on the computer monitor for 3 seconds and were then replaced by a blank screen, and adaptation top-up followed each response. The top-up procedure was identical to that described for adults, except the level of facial distortion was $\pm 90\%$.

Memory trials were identical to those used in Experiments 1a and 1b with one exception, faces were distorted by $\pm 90\%$ instead of $\pm 60\%$.

Results

Attractiveness Trials

Mean attractiveness ratings were calculated for each distortion level (-70, 0, +70) pre- and post-adaptation for the race that was expanded during adaptation and for the race that was compressed. A 2 (adaptation condition: expanded and compressed) x 2 (time: pre- and post-adaptation) x 3 (distortion level: -70, undistorted and +70) repeated measures ANOVA was conducted to determine whether shifts in attractiveness ratings were specific to adapting condition. Race was not included as a factor in the ANOVA; each adaptation condition consisted of ratings from both Caucasian and Chinese faces. For each adaptation condition half of the ratings were from Caucasian faces and half were from Chinese faces, because half of the participants were adapted to compressed Chinese faces and the other half were adapted to compressed Caucasian faces. There was a main effect of time, $F(1,23) = 33.47, p < .0001, \eta_p^2 = .59$, and a main effect of distortion level, $F(2, 23) = 11.95, p < .0001, \eta_p^2 = .34$. As shown in Figure 7, there was an overall

increase in attractiveness ratings post-adaptation. There was a significant two way interaction—time by distortion level, $F(2, 46) = 5.28, p < .01, \eta_p^2 = .18$. The main effects and two-way interaction were qualified by the significant three-way interaction, $F(2, 46) = 5.46, p < .01, \eta_p^2 = .19$. There was an increase in attractiveness ratings pre- to post-adaptation that was specific to adaptation condition, such that following adaptation to the race of face that was expanded during adaptation ratings for expanded faces increased and following adaptation the race of face that was compressed during adaptation ratings for compressed faces increased.

As with the adult data, we conducted separate two-way ANOVAs for pre- and post-adaptation ratings: adaptation condition x distortion level. For pre-adaptation trials there was only a main effect of distortion level, $F(2, 46) = 18.72, p < .001, \eta_p^2 = .44$. Tukey's PLSD revealed that undistorted faces were rated as more attractive than both compressed and expanded faces, $ps < .001$; expanded faces tended to be rated as more attractive than compressed faces, $p = .05$. All other effects were nonsignificant, $ps > 0.50$. For the post-adaptation ratings there were no main effects, $ps > .10$, but there was a significant two-way interaction $F(2, 46) = 7.53, p = .001, \eta_p^2 = .24$. A one-way ANOVA for ratings after adaptation to expanded faces revealed a significant effect of distortion level, $F(2, 46) = 4.75, p < .05, \eta_p^2 = .17$. Fishers PLSD revealed that both expanded and undistorted faces were rated as more attractive than compressed faces, $ps < .05$ and that, unlike pre-adaptation, undistorted faces were no longer rated as more attractive than expanded faces, $p > .50$. A one-way ANOVA for ratings after adaptation to compressed faces revealed a significant effect of distortion level, $F(2, 46) = 4.42, p < .05, \eta_p^2 = .16$. Fishers PLSD revealed that both compressed and undistorted faces were rated as more

attractive than expanded faces, $ps < .05$ and that, unlike pre-adaptation, undistorted faces were no longer rated as more attractive than compressed faces, $p > .40$.

To directly compare pre- versus post-adaptation attractiveness ratings within compressed and expanded facial distortions across the two adapting conditions, difference scores were calculated for each distortion level (e.g., attractiveness ratings for -70% faces pre-adaptation minus attractiveness ratings for -70% faces post-adaptation for the race of face that was compressed during adaptation and for the race of face that was expanded). Single-sample t-tests revealed that attractiveness ratings significantly increased for three out of the four conditions, $ps < .01$; only ratings of expanded faces after adaptation to compressed faces did not increase post-adaptation, $p > .90$.

Nonetheless, as shown in Figure 7, the increase in attractiveness ratings was larger for faces that matched the adaptation condition than for faces that did not. A 2 (face distortion : -70% and $+70\%$) \times 2 (adaptation condition: race of face expanded during adaptation and race of face compressed during adaptation) repeated measures ANOVA with pre- versus post-adaptation difference scores revealed a significant main effect of distortion level, $p < .05$ and a significant two-way interaction, $F(1, 23) = 9.84$, $p < .01$.

Paired two-tailed t-tests were then conducted to determine whether difference scores were greater in magnitude for the distortion that matched the adapting condition (i.e., -70% difference scores following adaptation to compressed faces compared to -70% difference scores following adaptation to expanded faces). When $+70\%$ difference scores were compared, the mean difference was significantly larger following adaptation to expanded faces ($M \text{ difference} = 1.08$) than for adaptation to compressed faces ($M \text{ difference} = .58$), $t(23) = 2.40$, $p < .05$. When -70% difference scores were compared,

the mean difference was significantly larger following adaptation to compressed faces (M difference = 1.67) than for adaptation to expanded faces (M difference = 0), $t(23) = 2.68$, $p < .05$.

Normality trials

Most children selected the undistorted face pre-adaptation in all four conditions (range = 17 to 22 children out of a possible 24 children) and preferences shifted in the expected direction post-adaptation. To analyze these results two different analyses were performed. The first analysis focused on whether individual participants shifted in the expected direction across all four trial types (e.g., trials with compressed faces for the race that was compressed during adaptation), a pattern that would be consistent with opposing aftereffects. For each of four pairs of pre- and post-adaptation trials (e.g., Caucasian trials in which one face had expanded features, Chinese trials in which one face had compressed features) we assigned a score of +1 if the selection shifted in the direction of adaptation, a score of -1 if the selection shifted in the direction opposite to adaptation, and a score of 0 if there was no change in the selection made. For example, if the child was adapted to expanded Caucasian faces and selected the undistorted Caucasian face pre-adaptation but selected the expanded Caucasian face post-adaptation a score of +1 was awarded. That child would also receive a score of +1 if they selected the compressed Caucasian face pre-adaptation but the undistorted Caucasian face post-adaptation. We assigned a score of -1 if the selection was in the direction opposite to adaptation. For example, if the child was adapted to expanded Caucasian faces and selected the undistorted Caucasian face pre-adaptation but selected the compressed Caucasian face post-adaptation a score of -1 was awarded. When the selection did not

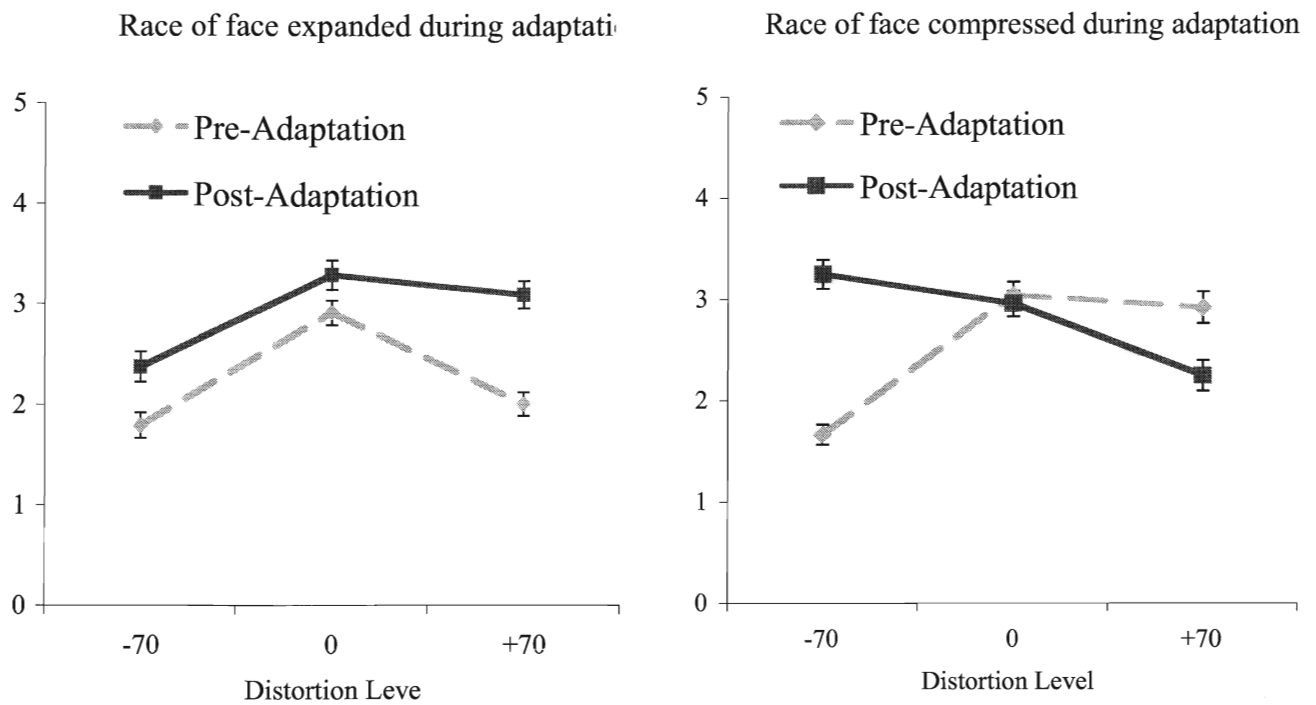


Figure 7. Experiment 2: Eight-year-olds' mean attractiveness ratings (± 1 SE) for each distortion level pre- and post-adaptation for the face race that was expanded during adaptation (left panel) and the face race that was compressed during adaptation (right panel).

change after adaptation (e.g., when a child selected the undistorted face or the compressed face both times) a score of 0 was awarded (see Appendix 1). The mean adaptation score ($M = .62$, $SE = .21$) was significantly greater than zero, as indicated by a single-sample two-tailed t-test, $t(23) = 3.02$, $p < .01$.

The second analysis focused on whether the proportion of children who selected the unaltered face as most normal changed following adaptation for each of four trial types (e.g., trials in which the undistorted face was paired with a compressed face for the race of face that was compressed during adaptation; trials in which the undistorted face was paired with an expanded face for the race of face that was expanded during adaptation). Four separate Chi-square tests were performed, one for each trial type. For each Chi-square, the number of children who selected unaltered faces versus distorted faces pre-adaptation comprised the expected frequencies and the number of children who selected unaltered faces versus distorted faces post-adaptation comprised the observed frequencies. If opposing aftereffects were elicited in children there should be a significant increased probability that faces of the same race and distortion as the adaptation condition would be selected as more normal looking post-adaptation, but no significant increase for faces of the opposite distortion. As expected when adapted to the race of face that was expanded during adaptation participants were more likely to select expanded faces as more normal looking post-adaptation, $\chi^2(1, N = 24) = 24.38$, $p < .001$ but were not more likely to select compressed faces as more normal post-adaptation $\chi^2(1, N = 24) = 2.00$, $p > .15$. When adapted to the race of face that was compressed during adaptation participants were more likely to select compressed faces as more normal looking post-

adaptation, $\chi^2(1, N = 24) = 6.09, p < .05$ but were not more likely to select expanded faces as more normal post-adaptation, $\chi^2(1, N = 24) = .54, p > .40$.

Memory Trials

A paired t-test was used to determine whether identification accuracy differed as a function of face race. Unlike adults, 8-year-olds showed no overall difference in recognition for Caucasian (M correct = 4.62, $SE = 1.7$) versus Chinese ($M = 4.42, SE = .21$) birthday guests, $t(23) = 1, p > .30$ (two-tailed).

Discussion

Eight-year-olds showed opposing aftereffects for race of face, following adaptation to faces with 90% facial distortions. Evidence of opposing aftereffects were demonstrated both when rating faces on attractiveness and when selecting the most normal face from a face pair. Opposing aftereffects for attractiveness were demonstrated in several ways. First, unlike pre-adaptation when unaltered faces were rated as most attractive, post-adaptation attractiveness ratings for distorted faces that were consistent with adaptation stimuli did not differ from ratings of unaltered faces; both were rated as more attractive than distorted faces that were inconsistent with adaptation stimuli. Second, increases in attractiveness ratings were largest for faces that matched the adapting condition. Ratings of expanded faces only increased following adaptation to expanded faces of the same race; ratings of compressed faces increased following adaptation to both expanded and compressed faces, but the increase was largest following adaptation to compressed faces of the same race. Third, opposing aftereffects for face normality were evident in the increased probability of children selecting expanded faces as more normal for the race of face that was expanded during adaptation but not for the

race that was compressed; the reverse pattern was observed following adaptation to compressed faces. These changes in the probability of expanded/compressed faces being selected as most normal were consistent with changes within individuals calculated across the four trial types.

These results are impressive given that children rated attractiveness for only one face per distortion level both pre- and post-adaptation (as in Anzures et al., 2009). In addition, on normality trials, unaltered faces were paired with a significantly distorted face ($\pm 50\%$). It is remarkable that after reading a 6-minute storybook they selected distorted faces as more normal on some trials. In contrast, adults were asked to select one of two slightly distorted faces ($\pm 10\%$). Collectively, these results indicate that 8-year-olds do have category contingent prototypes, similar to those of adults.

General Discussion

The Purpose of the Thesis

The purpose of my thesis was to investigate the nature of children's face space using opposing aftereffects. For this to occur I first had to validate my child-friendly method by eliciting opposing aftereffects in adults. Second, I had to determine whether 8-year-olds, like adults, would show opposing aftereffects following adaptation to distorted faces that belonged to two categories (e.g., Caucasian faces and Chinese faces).

It took extensive pilot testing ($n = 96$) and one failed experiment (Experiment 1a), to create a child-friendly method that demonstrated patterns consistent with opposing aftereffects in adults (Experiment 1b). In Experiment 1b, adults were more likely to select the expanded member of each pair for the race of face that was expanded during adaptation than for the race of face that was compressed during adaptation.

I am the first person to show that opposing aftereffects can be elicited in 8-year-old children and I did so by using a slightly modified version of the method used in Experiment 1b. Opposing aftereffects were shown in children using two different measures: attractiveness ratings and selection of face normality. Evidence of opposing aftereffects was shown when pre-adaptation measures were compared to post-adaptation measures. Prior to adaptation 8-year-olds rated unaltered faces, regardless of race, as more attractive than distorted ($\pm 70\%$) faces. Following adaptation, 8-year-olds' attractiveness ratings increased more for faces that were similar to adapting stimuli on both race (e.g., Caucasian) of face and distortion type (e.g., compressed) than for faces with the opposite distortion, such that faces consistent with adaptation stimuli were no longer rated as less attractive than undistorted faces. Similarly pre-adaptation, 8-year-olds selected the unaltered face as being more normal looking when they were given the choice between an unaltered face and a distorted face that was either compressed or expanded by 50%. Conversely, post-adaptation the proportion of 8-year-olds selecting distorted faces as more normal looking increased if the faces had a similar distortion and were of the same race as the adapting stimuli.

These results suggest that following adaptation to two face categories (Caucasian faces and Chinese faces) 8-year-olds' ratings for attractiveness and normality shifted in directions specific to the adaptation condition (e.g., expanded and compressed faces). These observed opposing aftereffects demonstrate the first evidence for 8-year-olds having multiple face prototypes.

What it Means for Children to Show Opposing Aftereffects

Only recently have there been simple aftereffect studies investigating norm-based coding in children (Anzures, et al., 2009; Nishimura, et al., 2008). Both showed that children's prototypes are dynamically updated when new faces are encountered (Anzures, et al., 2009; Nishimura, et al., 2008), but neither addressed the specificity of aftereffects in children. The current study is the first to show evidence for opposing aftereffects in children and is the only study that addresses the specificity of aftereffects in children by demonstrating that children as young as 8-years of age adapt simultaneously to two distinct facial categories that are distorted in opposite directions. Based on these results we can state that, like adults, 8-year-olds have category-contingent prototypes.

Although we now know that children have multiple prototypes, the composition of their face space still remains unclear. One possibility is that children's face prototypes are independent (see Figure 3b) while a second possibility is that children's face prototypes are dissociable (see Figure 3c). To determine which of these two models is an accurate depiction of children's face space an investigation of whether children will show, like adults, a generalization of simple aftereffects across face categories is required (see Jaquet et al., 2008; refer to page 7). If aftereffects do not generalize to a different face category (e.g., from female to male) it would indicate that children have independent prototypes. In contrast, if aftereffects do generalize it would suggest that children, like adults, have dissociable but not independent prototypes (Jaquet et al., 2008).

One pattern that supports the hypothesis of dissociable prototypes is the small, but significant increase in attractiveness ratings for compressed faces for the race that was expanded during adaptation. This pattern suggests that in addition to eliciting opposing

aftereffects specific to adaptation condition, generalization from one face category (e.g., Chinese) to another (e.g., Caucasian) is also occurring. Generalization can only occur if prototypes are dissociable, rather than independent. This may explain why opposing aftereffects typically are smaller than simple aftereffects (Andersen & Wilson, 2005; Anzures et al., 2009; Bestelmeyer et al., 2008; Jaquet & Rhodes, 2008; Leopold et al., 2001; Rhodes et al., 2003; Webster & MacLin, 1999; Webster et al., 2004).

Prior to two recent studies showing adaptation aftereffects in children, a plausible explanation for the gradual development of adult-like face expertise was children's failure to use norm-based coding. Evidence of simple identity and attractiveness aftereffects in 8-year-old children (Anzures et al., 2009; Nishimura et al., 2008) demonstrate that, like adults, children have prototypes that are dynamically updated as a result of face experience. My results suggest another plausible explanation: that children do not use category-specific prototypes. Future research is needed to explore the extent to which children rely on fewer dimensions within each category (see Nishimura et al., in press) and are less sensitive to differences among faces within dimensions (see Mondloch et al., 2002).

The Contingences for Eliciting Opposing Aftereffects

While attempting to validate my child-friendly method I discovered that opposing aftereffects are contingent on the context in which adapting stimuli are presented (refer to Experiments 1a and 1b). This discovery was made as a result of developing a child-friendly method. Most of the published opposing-aftereffect studies have the same basic adaptation procedure: Participants are asked to look at faces belonging to two different face categories, faces from each category are shown individually and face presentation

alternates between categories for a period of 2-minutes (Jaquet et al., 2007; Jaquet et al., 2008; Little et al., 2005; Rhodes et al., 2004). The success of this paradigm in eliciting opposing aftereffects may explain why there are no published studies that digress from this popular method.

For the purpose of my study, I attempted to elicit opposing aftereffects using a different method. I choose a method previously shown to elicit simple aftereffects in children (Anzures, et al., 2009). My adaptation procedure consisted of participants being read a storybook in which adapting stimuli were presented in one of two contexts. In Experiment 1a adapting faces were presented in the context of a surprise birthday party in which all of the guests were friends and were working toward a common goal of finding the birthday boy. The presentation of adaptation faces varied across pages; some pages included only Caucasian faces, some included only Chinese faces and others included both races. In Experiment 1b the presentation of faces was more similar to that of typical opposing aftereffect studies in which faces from two categories alternate from one page to the next and are never seen together.

There are two main interpretations for why opposing aftereffects were elicited in Experiment 1b but not in Experiment 1a; these interpretations are not mutually exclusive. The first interpretation proposes that the storyline accounts for the observed results, whereas the second interpretation proposes that way in which own- versus other-race faces were presented (whether the faces were shown together or separately) accounts for the pattern of results.

Storyline

The storylines in Experiment 1a (the Integrated Storybook) and Experiment 1b (the Segregated Storybook) differed in two fundamental ways, the first being the plot and the second being the relationships amongst the storybook characters. The integrated storybook was about a missing birthday boy, Dan, and the search to find him in time for his surprise birthday party. The storybook characters were depicted as being friends all of whom were working together to find Dan. The participants were involved in the search by being asked questions pertaining to the storybook's pictures, e.g., "Do you see Dan anywhere here?" In contrast, when reading the segregated storybook Calvin, the narrator, and the participant attended two birthday parties that were occurring at the same time. The two parties were kept separate with storybook characters from one party being friends with one another and the storybook characters at the other party being friends with one another but no friendships were observed between the characters attending different parties. The participants were asked questions that pertained to the activities being observed, e.g., "Have you ever played pin the tail on the elephant?"

The finding of opposing aftereffects only when faces were presented in the context of two segregated birthday parties raises some interesting questions about the mechanisms underlying opposing aftereffects. One interpretation of the results may be related to Levin's (1996, 2000) work using visual search paradigms to examine the other-race effect. He suggests that other-race faces are primarily encoded based on a single feature—race. Encoding faces solely on the feature of race interferes with encoding facial characteristics used for individuation, resulting in deficits in recognizing that face at a latter time and in the perception of other-race individuals being more homogeneous than

own-race individuals. In contrast, encoding facial characteristics that individuate a face, as is typical for own-race faces, results in more semantic processing and in a greater ability to recognize the face at a later time.

It could be argued that the Integrated Storybook's plot forced participants to individuate all of the characters. As the search for the birthday boy ensued, participants were repeatedly asked "Do you see Dan?", and their responses were followed by a statement like "You're right. There is only Julie and Bill wrapping the presents..." This discourse with the participants may have inadvertently caused participants to individuate Dan, the Chinese birthday boy, and may have reinforced the individuation of the other Chinese storybook characters. The individuation of the storybook characters likely reduced the salience of race as a feature and may have affected the categorization of faces. Rather than being categorized as Chinese children, faces may have been processed at the individual level, reducing the salience of the two race categories. Regardless, it is possible that categorizing all of the children as belonging to one group (e.g., children attending a birthday party) resulted in diminished or no observable opposing aftereffects, a pattern consistent with two previous studies showing the importance of face categorization for opposing aftereffects (Bestelmeyer et al., 2008; Jaquet et al., 2007).

Conversely, the Segregated Storybook's plot may have encouraged participants to categorize the storybook characters as belonging to two different groups (e.g., guests attending the Caucasian party and guests attending the Chinese party). Similar to the Integrated Storybook, all of the characters were referred to using common names like Bill and Julie. However, unlike the Integrated Storybook there was no need to remember the characters' names. The storyline never singled out any one character, even the birthday

boys. Therefore there was no need to individuate the characters within the Segregated Storybook; this may have resulted in the categorization of storybook characters based on face race allowing for opposing aftereffects.

The second difference between the storylines in the Integrated and Segregated Storybooks were the relationships amongst the characters. In the Integrated Storybook Caucasian and Chinese characters were shown as being friends with each other, whereas in the Segregated Storybook friendships were only depicted within a race (e.g., Caucasians were friends with Caucasians). A theory known as the extended contact effect can be used to explain why opposing aftereffects were only observed following adaptation to faces in the segregated story.

The extended contact effect is comprised of two parts: the self and peer relationships (Wright, Aron, McLaughlin-Volpe, & Ropp, 1997). Individuals who are like the self form an in-group, which is incorporated into the self's schema. These in-group members are reflected upon with positive attitudes. In contrast, individuals who are unlike the self form an out-group and are thought of with irrational negative prejudices. However, if the self or if members within the in-group are friends with members of the out-group, the out-group also becomes incorporated into the self's schema thereby decreasing the salience of the out-group and removing the negative prejudice associated with the out-group. This only occurs when the relationship between the self or the in-group towards members of the out-group is one of friendship. This is not observed if the peers are neutral acquaintances or enemies (Wright et al., 1997).

The participants for both Experiment 1a and Experiment 1b were Caucasian, suggesting that participants formed an in-group (Caucasian storybook characters) and an

out-group (Chinese storybook characters). In the Integrated Storybook all of the characters were friends. As suggested in the extended contact effect, when in-group members are friends with out-group members the salience of the out-group is removed and the out-group becomes incorporated into the concept of the self. By having all of the characters as friends in the Integrated Storybook, the out-group may have been eliminated, resulting in no opposing aftereffects being observed.

The results from the Integrated Storybook suggest that although faces from two categories (e.g., Chinese and Caucasian) may differ physically, the extent to which they are processed in relation to distinct prototypes may be modulated by top-down processing. If adults had independent prototypes (see Figure 3B), the context in which faces are presented should not affect adaptation or the observed aftereffects. However context does matter, as shown by the Integrated Storybook. Therefore these results support Jaquet et al.'s (2008) dissociable prototype model (see Figure 3C). Although the two categories of faces presented in the Integrated Storybook were physically different, they most likely were categorized as belonging to the same category (i.e., the in-group) possibly activating facial coding dimensions that overlap and canceling the effects of prototypes simultaneously shifting in opposite directions.

The Integrated and Segregated Storybooks provided participants with similar exposure to Chinese and Caucasian faces that were distorted in opposite directions. The finding that opposing aftereffects were evident in only one storybook suggests that top-down mechanisms modulate activity in the fusiform face area and play a role in face categorization (see also Bestelmeyer et al., 2008; Rhodes et al., 2007). Therefore the context in which faces are presented may impact broad neural networks throughout the

cortex that are involved in face processing, resulting in different levels of activation or firing frequency across neural populations within the neural networks depending on which face prototypes are being elicited.

Face presentation

The second main interpretation for why opposing aftereffects were observed in Experiment 1b (the Segregated Story) but not Experiment 1a (the Integrated Story) could be how the adapting stimuli were presented. In the Integrated Story, faces of both races were presented together on some pages. In the Segregated Story, faces of each race were shown on separate pages and race of face alternated from page to page.

The possibility that face presentation may have influenced opposing aftereffects in Experiment 1b is consistent with the meta-analysis performed by Meissner and Brigham (2001). Meissner and Brigham (2001) reported that when race of face is blocked, i.e., when one race of face shown is shown per testing block rather than trials being intermixed, there is a significant increase in the difference between recognition accuracy for own-race faces versus other-race faces. Their findings suggest blocking faces increases the salience of race, resulting in a stronger other-race effect (Meissner & Brigham, 2001). Presenting faces of both races on the same page in the Integrated Storybook may have decreased the salience of race interfering with categorization by race. Instead, what may have happened was participants categorized the faces as belonging to the self (previously described using the extended contact effect) or categorizing all of the faces as children's faces.

The data collected from the memory trials provides support for this explanation. Difference scores were calculated for adults' accuracy of correctly identifying own-

versus other-race faces for each storybook (the Integrated Storybook and the Segregated Storybook). The difference scores were calculated by taking the number of correctly identified Caucasian characters (own-race faces) and subtracting these from the number of correctly identified Chinese characters. Single-sample t-tests (one tailed) revealed that participants were more likely to correctly identify Caucasian storybook characters than Chinese storybook characters after being read both the Segregated Storybook, $t(18) = 6.83, p < .0001$ and the Integrated Storybook, $t(23) = 2.03, p < .05$. A one-tailed independent samples t-test revealed that there was a significantly larger own-race advantage after reading the Segregated Storybook than after reading the Integrated Storybook, $t(41) = 2.66, p < .01$. These results indicate that blocking for race increased both the own-race recognition advantage and opposing aftereffects, likely because it increased the salience of face race.

An alternative, but unlikely explanation for opposing aftereffects is the mere exposure effect. The mere exposure effect describes how previously viewing an object increases a preference for that object or ones similar to it at a later time (Zajonc, 2001). In the current context, exposure to expanded Chinese faces and compressed Caucasian faces in the storybook would result in increased attractiveness/normality ratings for similar faces after reading the storybook; according to the mere exposure effect there is no need to invoke prototypes. However, the mere exposure effect does not explain why exposure to oppositely distorted faces in the Integrated Storybook used in Experiment 1a did not produce shifts in normality judgments that were specific to exposure. Nor does it explain the failure to find opposing aftereffects following exposure to faces that belong to the same category (e.g., Chinese versus super-Chinese, Jaquet et al., 2007; female versus

hyper-female, Bestelmeyer et al., 2008). An ongoing study in which 8-year-old children are being tested with the Integrated Storybook will determine whether the opposing attractiveness aftereffects found in Experiment 2 can be explained by the mere exposure effect.

Memory Trials

The memory task followed the post-adaptation trials for both adults and 8-year-old participants. Results indicated that adults who read either the Integrated or Segregated Storybook demonstrated an own-race advantage, by accurately identifying more Caucasian storybook characters than Chinese storybook characters. However, this own-race advantage was not observed in 8-year-olds. Although children as young as 3-years of age have shown better recall for own-race faces when compared to other-race faces while completing an old/new memory task (Sangrigoli & de Schonen, 2004b), other studies, using similar testing paradigms have only been able to show an own-race advantage for children who were 9-years of age and older (Corenblum & Meissner, 2006; Goldstein, & Chance, 1980; Kask & Bull, 2009). These contradictory findings suggest that perhaps the own-race advantage may not be robust in young children, especially when faces are encoded in the context of an engaging storybook.

Unlike studies that measure face recognition using old/new and same/different paradigms, our participants' recognition of storybook characters was measured using face arrays. Our results do not appear to be a result of the face arrays being too difficult (i.e., floor effects) because participants' accuracy for face identification was well above chance (73% for Chinese characters and 77% for Caucasian characters). In addition, other studies that have used face arrays present 3 to 8 faces to children younger than 8-years of

age and have been shown to successfully measure face recognition (LoBue (2009) tested 5-year-olds; Seitz (2003) tested 4-year-olds).

Future Directions

In summary, I created a child-friendly method that elicited opposing aftereffects in both adults and 8-year-olds. I was the first to show opposing aftereffects in 8-year-olds and I discovered that, at least for adults, opposing aftereffects are contingent on the context in which adapting stimuli are presented. By using the storybook for adaptation I can foresee my research being continued in two major directions. The first direction would be to investigate the development of face prototypes and the second would be to investigate the conditions necessary to elicit opposing aftereffects.

Investigating the development of face prototypes

Experiment 2 demonstrated that children have multiple prototypes but the results are consistent with both proposed models for multiple prototypes i.e., model B or model C of Figure 3. To address whether children have independent or dissociable prototypes two studies are proposed. The first, which has already started, has been designed to determine whether children will show opposing aftereffects following adaptation to the Integrated Storybook. If children show opposing aftereffects following this form of adaptation it would indicate that the context in which Caucasian and Chinese faces are presented does not affect children's face categorization in the same way as adults' face categorization. Because all storybook characters are children, 8-year-olds may readily classify the Chinese children as an out-group and the Caucasian children as an in-group, thus reducing the extended contact effect. In contrast, for adults, the storybook characters

of the Integrated Storybook may all be categorized as belonging to a single out-group—children.

The second study should determine whether children, like adults, will show generalized simple aftereffects. After being adapted to female compressed faces adults rate female compressed faces as more attractive post-adaptation and to a lesser degree they also rate male compressed faces as more attractive post-adaptation (Jaquet et al., 2008). These results are consistent with dissociable prototypes given that dissociable prototypes have overlapping dimensions. The magnitude of the aftereffects is important, in that they are larger for faces that belong to the same category (e.g., female) as the adapting stimuli and are smaller for faces that belong to a different category (e.g., male). If however adults had not shown generalized aftereffects, this would have indicated that they had independent prototypes and that the facial dimensions used to code faces of each category were separate. If children show generalized aftereffects it would suggest that they too have dissociable prototypes and if they do not show generalized aftereffects it would indicate they have independent prototypes.

Third, it will be important to test younger children on this task to determine when opposing aftereffects emerge. We have shown (Mondloch et al., 2009) that 5-year-olds show simple attractiveness aftereffects but nobody has tested children this young on opposing aftereffects. If 5-year-olds show opposing aftereffects for race of face, then the current method could also be used to investigate whether they show opposing aftereffects for other face categories (e.g., male/female; old/young). The present task may be a useful tool for investigating the refinement of children's face space. Depending on the results of

the first two future studies described above, 5-year-olds could be then tested to determine if they have independent or dissociable prototypes.

Understanding the conditions necessary for eliciting opposing aftereffects

The other direction in which I see this research going is to understand which conditions are necessary for eliciting opposing aftereffects. To further delve into the mystery surrounding the effects that I have explained based on the extended contact effect, I can see creating two versions of the same storybook. The pictures in the two books would be identical and both races would be shown on every page but the story would depict the relationship between the Chinese and Caucasian children as friendly and cooperative or as unfriendly and antagonistic. As shown by the extended contact effect, the out-group is only incorporated into the self's schema when the self has friends in the out-group or the other in-group members have friends who belong to the out-group. If opposing aftereffects are elicited by the antagonistic version but not the cooperative version it would add significant support to the claim that facial categorization and prototypes are not solely dependent on physical differences but also are modulated by top-down processes. This would be consistent with a recent study done by Bernstein, Young, and Hugenberg (2007). Bernstein et al., (2007) demonstrated an effect similar to the other-race effect but all of stimuli were Caucasian male faces. They found by labeling some faces as being from the participant's own university (the in-group) other faces as being from a rival university (the out-group), recognition accuracy for own-university faces was better than recognition of other-university faces. These findings suggest that the context in which faces are presented impacts how faces are categorized and processed.

Summary

While completing my MA thesis I made two novel discoveries. The first was that opposing aftereffects are contingent on the context and the way in which adapting stimuli are presented. The second was that 8-year-olds, like adults, have multiple face prototypes that can be shifted in opposite directions for distinct face categories. One implication these results have is that the gradual development of face expertise is not the result of children failing to encode faces relative to category-specific prototypes; rather within each category they may rely on fewer dimensions or be less sensitive to differences among faces within dimensions (see page 15). My research program points out the need to integrate across disciplines within the field of psychology (e.g., social psychology, developmental psychology and the study of perception) in order to fully understand the nature of human development. Most importantly my results provide a strong foundation for future research.

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Appendix 1

3

Adapted to Compressed Faces

Participant	Pre-Adaptation		Post-adaptation		Pre-Adaptation		Post-adaptation		Score
	Undistorted	Compressed	Undistorted	Compressed	Undistorted	Expanded	Undistorted	Expanded	
S1	1	0	1	0	1	0	0	1	-1
S2	1	0	1	0	1	0	1	0	0
S3	1	0	1	0	1	0	1	0	0
S4	1	0	0	1	1	0	1	0	1
S5	1	0	1	0	1	0	1	0	0
S6	1	0	1	0	1	0	1	0	0
S7	1	0	0	1	1	0	1	0	1
S8	0	1	1	0	1	0	1	0	-1
S9	1	0	0	1	0	1	1	0	2
S10	1	0	0	1	1	0	1	0	1
S11	1	0	1	0	1	0	1	0	0
S12	1	0	1	0	1	0	1	0	0
S13	1	0	1	0	1	0	1	0	0
S14	0	1	1	0	1	0	0	1	-2
S15	1	0	1	0	1	0	1	0	0
S16	1	0	0	1	1	0	1	0	1
S17	1	0	1	0	1	0	1	0	0
S18	0	1	0	1	1	0	1	0	0
S19	1	0	0	1	1	0	1	0	1
S20	1	0	1	0	0	1	0	1	0
S21	1	0	1	0	1	0	1	0	0
S22	0	1	1	0	1	0	1	0	-1
S23	1	0	1	0	1	0	1	0	0
S24	1	0	1	0	1	0	1	0	0

Adapted to Expanded Faces

Participant	Pre-Adaptation		Post-Adaptation		Pre-Adaptation		Post-Adaptation		Score
	Undistorted	Compressed	Undistorted	Compressed	Undistorted	Expanded	Undistorted	Expanded	
S1	1	0	1	0	1	0	1	0	0
S2	1	0	1	0	1	0	1	0	0
S3	0	1	1	0	1	0	0	1	2
S4	1	0	1	0	1	0	1	0	0
S5	0	1	1	0	1	0	1	0	1
S6	1	0	1	0	1	0	0	1	1
S7	1	0	0	1	1	0	0	1	0
S8	1	0	1	0	0	1	0	1	0
S9	1	0	1	0	1	0	1	0	0
S10	1	0	0	1	1	0	0	1	0
S11	1	0	1	0	1	0	1	0	0
S12	1	0	0	1	1	0	1	0	-1
S13	0	1	1	0	1	0	1	0	1
S14	1	0	1	0	1	0	0	1	1
S15	1	0	1	0	1	0	0	1	1
S16	1	0	1	0	1	0	1	0	0
S17	1	0	1	0	1	0	0	1	1
S18	0	1	1	0	1	0	0	1	2
S19	0	1	1	0	1	0	1	0	1
S20	1	0	1	0	0	1	0	1	0
S21	0	1	1	0	1	0	1	0	1
S22	1	0	1	0	1	0	1	0	0
S23	1	0	1	0	1	0	0	1	1
S24	1	0	1	0	1	0	0	1	1